

***Civil and Architectural Engineering***

**Water Treatment With Conventional and Alternative  
Coagulants: A Review**

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**ABSTRACT**

There is no access to basic sanitation for half the world's population, leading to Socioeconomic issues, such as scarcity of drinking water and the spread of diseases. In this way, it is of vital importance to develop water management technologies relevant to the target population. In addition, in the separation form of water treatment, the compound often used as a coagulant in water treatment is aluminum sulfate, which provides good results for raw water turbidity and color removal. Studies show, however, that its deposition in the human body, even Alzheimer's disease, can cause serious harm to health and disease development. The study aims to improve the coagulation/flocculation stage related to the amount of flakes, including the absence of metal sludge formed. Initial studies were concerned with assisting and comparing natural and chemical coagulants. The key chemicals used for coagulation are aluminum sulfate (alum) and poly aluminum chloride, also known as PACL and ferric chloride.

**Keywords:** Coagulants, Flocculation , Turbidity Removal, Water treatment.

**معالجة المياه بالمخثرات التقليدية والبديلة**

الطالبة

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**الخلاصة**

يعاني نصف سكان العالم من مشاكل اجتماعية واقتصادية بسبب ندرة مياه الشرب وانتشار الامراض ، والذي يحتم ادارة وتطوير تقنيات معالجة المياه للاستفادة منها بتوفير المياه الصالحة للشرب. وبشكل عام فإن معالجة المياه تتم بعدة عمليات وهي ما يستخدم المركب كبريتات الالمنيوم ( الشب ) للتحتر التخبثر والتلبيد والترسيب والتصفية والتعقيم ففي عملية التخبثر غالبا الخام ، ولكن تشير بعض الدراسات الى ان ترسب والذي بدوره يوفر نتائج جيدة في ازالة العكارة واللون في الماء ضررا خطيرا على الصحة العامة وتطور المرض ، الالمنيوم في جسم النسان يسبب مرض الزهايمر والذي بدوره يسبب

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كمية المواد المترسبة والتخلص من الحمأة المعدنية لذا فان الهدف من الدراسة هو تحسين مرحلة التخثر / التليد بتقليل المتكون اثناء الترسيب لذلك فان الدراسة الاولية اهتمت بإمكانية استخدام مواد بديلة لعملية التخثر وهي كلوريد الحديد والالمنيوم والمواد الطبيعية مثل مورنكا الالوفيرا بدلا من مواد التخثر الكيميائية المعروفة وبولي كلوريد وهي كبريتات الالمنيوم (الشب).  
الكلمات الرئيسية: التليد ، التخثر ، معالجة المياه ، إزالة التعكر

## 1. INTRODUCTION

In different fields, clotting and flocculation are important processes. Clarification of water by coagulant agents since ancient times has been done in drinking water treatment. Even in 2000 BC, the Egyptians used ammonium to stain the water by boats. Alum was referenced in approximately 77 AD as a coagulant by the Romans. In the city's water treatment in England, alum was used for coagulation by 1757.

Modern water processes also include coagulation and flocculation – understandably, since 1989, the US's regulatory cap for treated water turbidity has gradually fallen from 1.0 NTU (1989) to 0.3 NTU today. Many water suppliers are dedicated to providing water turbidity treatments of less than 0.1 NTU to prevent pathogens.

In many wastewater treatment operations, coagulation is also necessary. Chemical phosphorus reduction is a typical example, whereas the chemically enhanced primary treatment practice of crowded wastewater treatment plants reduces suspended solids and organic loads from primary clarifiers (**Bratby, J. 2016**).

The care of water is one of the world's most significant practices. The most frequent treatment methods used in potable water processing include coagulation, flocculation, sedimentation, filtration, and disinfection. In extracting suspended solids, coagulation and flocculation processes are very important. Flocculation is used to separate the suspended component of solids from the water by means of both groundwater and surface water (**Baptista, et al. 2015**).

Suspended particles differ in source, load, particle size, form, and density, based on the application of coagulation. Suspended solids have a negative charge of water, and since they have the same surface load, as they come together, they repel each other. Suspended solids are therefore suspended and not clumped together or settling down from the water until proper coagulation and flocculation have been added. Coagulation and flocculation happen in successive phases, which allow for a collision of particles and flocculation growth. If the coagulation is insufficient, there is no good flocculation, and sedimentation is inefficient if it is not complete. Previous studies from (**Crappier et al. 1973**) and (**Miller et al. 1984**) found that the medication used to purify water would pose significant health risks if a mistake happens during the treatment phase of their administration. The findings indicated that elevated aluminum levels in the brain constitute a risk factor for Alzheimer's. However, no definitive proof was found in (**Davis, 2006**) that connected aluminum to Alzheimer's disease. Studies have raised concerns about the advisability to add aluminum into the atmosphere by continuous use of alum-sulfates as a water coagulant (**Miller et al., 1984**) and (**Alward, et al. 2015**).

For human survival, intake of drinking water is important. There is a freshwater cap in our world (0.8 percent of water globally). 97% of the water is freshwater, and just 3% is surface water. However, it is also unfit for human use and must be removed to lift it to drinking levels.



In determining the consistency of the effluents treated, the color, the turbidity, and the acceptability of water for human use are important criteria to consider. The appearance of colorful and turbid particles could render water appear esthetically undesirable and could theoretically make customers drink from other less safe beverages. Furthermore, these particles may shelter microorganisms and make disinfection less effective. In order to achieve the necessary standards of acceptability, it is necessary to extract colloidal particles that convey turbidity or color, such as proteins, minerals, and organic matter. The colloidal particles mostly have negative electrical loads on their surfaces, which create repulsive barriers and avoid aggregation. To eliminate colloids through subsequent sedimentation, flotation, or filtration, it is important to facilitate changes in the surface properties of particles by the addition of coagulants, typically aluminum or ferric salts (**Chowdhury, et al. 2009**).

## 2. COAGULATION

In order to neutralize the negative charges for unstable compounds, chemicals with charging opposite to that of the suspended solids are applied to the water (such as clay and color-producing organic substances). The tiny suspended particles will bind together until the charge is neutralized. These smaller particles are referred to as colloids and are not apparent to the naked eye. Water should be transparent around the newly formed colloid. A strong, rapid mix is required to correctly disperse and facilitate particle collisions (**Abdulmajeed, et al. 2015**).

## 3. FLOCCULATION

Flocculation, a mild mixing step, increases particle dimensions to observable particles from the submicroscopic collision. Particles may collide and cause the bonding of huge, transparent flowers known as pin flocs. The sizing of floc continued with incorporating inorganic polymers (coagulant) and organic polymers with additional collisions and contact. Macroflocks are created and can be added to help bridge, tie and stabilize the flock, add weight and improve the settling process. They are called coagulant aids. Water is ready for sedimentation until it reaches maximum size and weight. Contact periods range from 15 minutes to 20 minutes or more for flocculation, and careful consideration of mixing speed and energy is needed for flocculation. The mixing speed and energy normally taper off as the floc size grows to avoid floc breaking apart or shaving. It is hard to get the flocks to reform their maximum size and power until they are ripped apart. The level of control by the operator available in flocculation depends heavily on the type of equipment and its configuration.

## 4. CONVENTIONAL PLANTS

Conventional plants are separated from the flocculation (or slow mixing) stage by coagulation (or quick-mix). Sedimentation and then filtration follows these steps. Water flows directly from flocculation to filtration for direct filtration. The raw water quality of these systems is typically higher. Conventional plants can change mix speeds both for fast mixing and slow mixing systems. There will be several feeding points for coagulants, polymers, flocculants, and other chemicals, and usually, sufficient space is available to isolate feeding points for incompatible chemicals. Conventional plants are subject to restrictive retention periods and rates of increase. This typically leads to demands for deep process basins and a large area for the plant site. On-site pilot plant assessments are recommended, before construction, by a skilled engineer familiar with water quality (**Hudson, 1981**).



The time that the water spends in the stream shall be retained (or detained). The fluid volume (in gallons) of a basin will be determined by the plant fluctuation rate (gallons per minute). The actual time of detention in a basin would be less than the estimated time of detention due to "empty zones" and short distances which could result from unsatisfactory confinement.

Retention time = basin volume (gallons) /gpm flow

Rise rate is calculated by dividing the flow in gallons per minute by the net water surface area of the basin in square feet.

Rise Rate = gpm flow/surface area

## 5. COAGULATION, FLOCCULATION, AND SEDIMENTATION COMBINED

Some models include coagulation, flocculation, and single unit sedimentation (either upflow solids contact units or sludge blanket units). Most touch units for upflow solids use recirculation to improve floc formulation and maximize the use of chemical treatments. Units of blowing blankets pull freshly forming flocks onto a suspended floc bed. The cross-sectional area of the basin increases from bottom to top in both types of units, slowing down the water flow and permitting floc to flow. In addition, combined units use higher rates of growth and faster incarceration than traditional therapy. Many producers sell ownership units based on these principles of architecture. The units are smaller and need less land for the position of the farm. Prior to construction, an on-site pilot plant assessment is recommended by a professional water quality engineer.

Water treatments are also a concern and cause of complications in many countries, including health-threatening toxic coagulants and organic dissolved carbon. The accomplishment of usage requirements includes water quality. Aluminum polychloride and aluminum sulfate are the most widely used inorganic/synthetic coagulants for coagulation/flocculation processes worldwide (**Baptista et al., 2015**). After the procedure, which is an essential issue of public health officials, high residual concentration may still exist. In fact, there is growing demand for the reliable, economical, readily available, and non-toxic alternative coagulants of natural origins (**Tukki et al., 2016, Lo Monaco et al., 2010**). According to the reports, concern for population health can therefore be intensified with aluminum, particularly with respect to Alzheimer's disease (**Flaten et al. 2001**).

## 6. COAGULANT SELECTION

Chemical selection of coagulants depends on the type of suspended solid to be collected, the conditions of the raw water, the plant's composition, and the chemical's cost. Final coagulant (or coagulant) selection should be performed with jar testing and plant scale assessment. The quality of the effluent needed has an impact on the efficiency of the downstream treatment process, on costs, and on the system (**Miller et al. 2008**).

### 6.1 Inorganic Coagulants



The most often employed inorganic coagulants are aluminum and iron salts. These heavily charged ions are added to water to neutralize the hanging particles. The constituent inorganic hydroxides generate short polymer chains to improve the formulation of micro flocs. Inorganic coagulants are often available at the lowest price per pound and are efficient in removing most suspended solids when used correctly. They are also able to remove certain chemical precursors from the disinfection by-products combined with chlorine. Large amounts of a floc are produced by inorganic coagulant agents that can also catch bacteria when settled. Since the water consumes alkaline, inorganic coagulants can change the pH of the water. When used as a method of lime ash softening, lime and soda ash are demanded by aluminum and iron salts. They also need storage and feeder equipment that resists corrosion. Worth noting is that vast quantities of deposited floc must be ecologically suitable disposed of. Higher alkalinity and pH reactions are observed for both alum, ferrous sulphate, and ferric chloride (Angelakis et al. 2014).

**Alum**



Aluminum Sulfate + Calcium Bicarbonate (present in the water to treat) gives Aluminum Hydroxide + Calcium Sulfate + Carbon Dioxide

**Ferric Sulfate**



Ferric Sulfate + Calcium Bicarbonate (present in the water to treat) gives Ferric Hydroxide + Calcium Sulfate + Carbon Dioxide

**Ferric Chloride**



Ferric Chloride + Calcium Bicarbonate (present in the water to treat) gives Ferric Hydroxide + Calcium Chloride + Carbon Dioxide

**6.2 Chemical coagulants**

Although several applications remain to treat domestic water, chemical coagulants are commonly used in urban drinking water treatment. The key chemicals used for coagulation are aluminum sulfate (aluminum), polyaluminum chloride (also known as PACL or liquid alum), aluminum potash and iron salts (ferrous chloride), lime, lime soda ash (Na2CO3), and caustin (CaOH2) (Fazeli, et al. 2014).



How will pollution be removed?

Turbidity-inducing particles (e.g., silt, clay) are normally charged negatively, making it difficult for them to clump together due to electrostatic repulsion. However, coagulant particles are positively charged and chemically drawn to the negative turbidity particles, neutralizing the negative charge of the latter, then collecting the neutralized particles by merging. Customary The following chemicals are based on organic formulations :

- Polydadmacs are the most commonly used organic coagulants of polyamine, cationic in nature, and act alone by neutralizing the charge. The negative charge of colloids is neutralized by cationic coagulants and they form a spongy mass called micro flocks .
- Formaldehydes and melamine tannins coagulate the colloidal content of water and absorb raw materials such as oil and grease. Lower dosage, a lower amount of sludge production, and no pH effects are the main benefits of organic coagulants. Inorganic coagulants with a wide range of water and wastewater are both cost-effective. Inorganic coagulants are highly efficient with low turbidity in raw water.

Examples of inorganic coagulants are as below:

- Aluminum Sulfate (Alum)-Water treatment chemicals are one of the most extensively used in the world. As a liquid that is dehydrated from the crystalline form, alum is formed.
- Aluminum chloride is a second alternative to alum, as it is more expensive, poisonous, and corrosive.
- Poly aluminum chloride (PACl) Advantages over alum and ferric salts include decreased acidity, positive charged monomers, and polymers preformed, fast and denser flock formation, and decreased sludge. The usage of coagulants has changed from the traditional turbidity removal role to one that includes multiple coagulation targets.
- Ferric Sulfate & Ferrous Sulfate-Ferric sulfate is the most often used, but ferrous sulfate is generally used in applications containing a reducing agent or excess soluble iron ions. Iron coagulants operate similarly to aluminum coagulants, although the cost can vary based on the local source of supply.
- The least costly inorganic coagulant produced as waste material from steel manufacturing operations is ferric chloride. However, the most corrosive and poisonous inorganic coagulant is by far the most corrosive, and its application is limited to installations equipped to handle it safely (**Camacho, et al . 2015**).

### 6.3 Natural coagulant :





### 6.3.1 Coagulants from plants (PBC)

The PBCs are widely used for water purification that is less urbanized because they tend to be less expensive than artificial coagulates. The treatment of water with a low to medium turbidity level (50 to 500) NTU is presumed with PBC coagulants. It is also unpredictable for the 21st century to provide a fully decisive review of the present PBC.

A. **Moringa oleifera (MO) crop** A natural plant with active bio-coagulate compounds which can be used for water clarification if it prevents the use of chemical-based coagulants. It is a tropical plant that belongs to the Moringa stopper genus. Seeds are brown, and kernels are whole white crushed seeds or press cake that remain after oil extraction as a coagulant.

- **Advantage of Moringa oleifera Coagulant over Alum**

- a) It is customary and absolutely non-toxic.
- b) The seed extract of M. Oleifera tends to have a natural buffering capacity, so pH alkalinity does not require any modifications.
- c) In addition to the degree of turbidity, it limits the amount of microorganisms in water.
- d) It is thoroughly biodegradable.
- e) In the case of Moringa, the volume of sludge produced is considerably less than in the case of alum.

- **Drawbacks of Moringa oleifera**

- a) Seed supply is actually a challenge that requires mass cultivation.
- b) The moringa oleifera probably shelled seed powder cost is greater than the cost of alum at present.
- c) Water that was extracted by moringa oleifera removes discoloration after two days of medication.
- d) Another water extract drawback improves dissolved organic carbon in treated water. (Muyibi, et al. 2002).

B. Nirmal polymers whose particles fade in water through interparticle bridges are anionic polyelectrolytes. The seed extracts contain  $-COOHs$  and  $-OHs$ , which enhance coagulation skills due to fluids, carbohydrates, and alkaloids. Galactomannani and galactanii are polysaccharide mixtures isolated from Strychnospotatorium seeds that can reduce turbidity to 80%. Galactomannans are generated in all aspects of 1,4-linked mien end  $\alpha$ -d-galactopyranosyl units of 0–6 point residue residual in all respects. (Yin, 2010).

C. Manioc skin. Three major effects of fresh cassava flakes: fast-spreading, containing phytates, and a large quantity of cyanogenic glycosides. Altered methods of sinking in cyanogenic glycoside such as solar drying, soiling, and soaking + sun drying are used to shrink the cyanogenic & Phytate content to preserve their natural value. Peelings are cut to achieve reasonable quality 2 cm for simple compression and are reduced to around 40% by 70-75% for two days. Cassava peel silage has been seen after 21 days as light brown with satisfactory odor in appearance. The pH was 4.4 with negligible fungal growth (Miller et al. 2008).



### 6.3.2 Non-plant-based coagulants

Polymeric coagulants retain cationic, anionic, or non-ionic, where two polyelectrolytes are sometimes commonly represented. Polymers are mostly artificial, and natural polyelectrolytes are durable when used for the disposal of wastewater. Previous experiments are conducted on natural coagulants known as "polyelectrolytes," but several of these studies did not basically carry out in-depth characterization and ionic activity of chemicals. Of course, polysaccharides or proteins are coagulants. Classified as non-ionic because of the absence of charge interactions, interactions can occur between partially charged polymer groups and a solvent (**Hassan, et al. 2009**). Chitosan is a natural polysaccharide with many useful lines such as hydrophilicity, biocompatibility and metal ion adsorption potential due to its amino groups. Chitosan is the most commonly transmitted cellulose biopolymer in nature, mostly in sea invertebrates, insects, yeast, and fungi. The chitin, a natural polysaccharide occurring mainly in arthropods and fungi, is the acetyl group and derives from the chitin. Chitosan contains behavior such as high molecular weight cationic polymers that are non-toxic, biodegradable, and linear. Moreover, the extraction of chitin does not induce flaps to the environment; it benefits all the benefits of polysaccharides (**Montembault et al. 2005**). Alginates are abundant in nature; all solar bacteria have capsular polysaccharides and aquatically brown algae (phaeophyceae) with a structural portion comprised up to 40% dry matter. Alginates are associated with their ability to maintain viscosity, gelling, and stabilization of water. It incorporates naturally carboxyle groups and different functional material capabilities, which is simply polysaccharide.

## 7. Conclusions and Recommendations

Natural coagulants are derived from many natural sources when primary coagulants or auxiliary coagulation /flocculation functions are present as viable and economical solutions. Two forms of natural and synthetic coagulants are found. There are double-formed coagulants, first plant-based coagulants, and second non-plant coagulants.

The use of natural coagulants effectively reduces water turbidity to sensitive values and can be used individually or in conjunction with aluminum. Using alum with natural coagulants is cleared of reducing the alum dosage by 50% with the same efficiency of elimination as the promising strategy. This could reduce both the cost of aluminum alone and the health risk. Next, studies will be carried out to analyze the economic and health challenges arising from the use of alum with a particular ratio of natural coagulants and how this alone decreases the costs of using alum. Various parameters, including temperature, are also tested.

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