**TREATMENT OF HIGH STRENGTH INDUSTRIAL WASTEWATER BY USING NATURAL COAGULANT – A REVIEW**

A.SathiyaPriya1, S.Sundararaman2, N. Pannirselvam3\*, J. Vanjinathan4, S.Kandasamy5, S.Azhagarsamy6

*1 Research Scholar, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Puducherry, India*

*2Professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Puducherry, India*

*3Associate Professor, Department of Civil Engineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur-603203, Tamil Nadu, India.*

*4Assistant Professor, Department of Civil Engineering, Sathyabama Institute of Sciences and Technology, Chennai, Tamil Nadu, India*

*5Professor, Department of Civil Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai-600062, Tamil Nadu, India*

*6Research Scholar, Department of Civil Engineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur-603203, Tamil Nadu, India.*

*\*Corresponding author E-mail: pannirsn@srmist.edu.in*

**Abstract:** The contamination present in the high strength wastewater discharged from various Industries release toxic compound to the environment and creates major threats to both human and environment. Different technologies were adopted for the treatment of high strength wastewater. However it has some drawbacks such as toxicity, sludge production and high production cost. This review paper present the recent technologies adopted in the treatment of high strength wastewater discharged from various industries like Textiles, Tannery, Pharmaceutical, Dye and Dairy industries by using natural coagulants. The main mechanism of Natural coagulant for high strength wastewater treatment is by the process of flocculation and charge neutralization. The Natural coagulant extracted from leaf, stem, root, bark and seed of a plant and tree are used as a natural coagulant, which is easily available at low cost and affordability. The application of natural coagulants helps to reduce the strength of wastewater and can be discharged within the prescribed limits and thereby implementing greener wastewater treatment technology.

**Key Words:** High strength wastewater, coagulation, Natural coagulants, Flocculation, Green Technology.

**1. Introduction**

High strength wastewater includes wastewater from Industries like Textiles, Tannery, Paper, Pharmaceutical, Chemical, Dye, Distillery, Dairy, and Paint and Pesticide these types of waste need some special treatment which has to degrade the complex compound into simple compound, and to reduce the toxicity. High strength wastewater is a liquid that has high concentration of BOD, TSS, COD and other complex compound higher than the discharge limits, which is discharged from factories and finding way to local water bodies to create threats to Human and Environment. The conventional method has some drawback due to its high cost, duration and availability. The treatment of wastewater carried in three ways Physical method, Chemical method and Biological method [3].Physical methods involves Sedimentation, filtration process whereas chemical methods involve chemical reactions and the biological methods involves aerobic and anaerobic processes. But each process has some disadvantages like chemical requirement, cost and sludge production. Therefore to treat the high strength wastewater, we need new technologies to be adopted by using some natural materials which are easily and at low cost. To treat the high strength concentration wastewater, natural coagulants like Grape seed extract, Banana peel powder, Neem seed powder, Papaya seed, Peanut seed, and Moringa oleifera (drumstick) seed powder are utilized.

**2. Coagulants**

Coagulants can be divided into two categories: natural and chemical. Natural coagulants are coagulants made from plants and animals found in the natural environment. Aluminum sulfate, ferric sulfate, ferric chloride, and poly aluminum chloride are some of the compounds used to make chemical coagulants. Natural coagulants come in three different varieties: those based on plants, animals, and microorganisms. The flower, seed, leaves, stem, bark, roots, and resin gums of plants and trees are used to make plant-based coagulants. The Chitosan found in the shells of crabs, lobsters, shrimp, diatoms, fungi, insects, freshwater and marine sponges, and mollusks is used to make animal-based coagulants [19]. The microorganism category consists of bacteria with extracellular polymeric substance can acts as a Bio coagulation /Bio flocculants.

**3. Coagulation Process**

Coagulation is a process of disintegrating the solids into small particles there by increasing the surface area of the particles so the coagulant can be more easily adsorbed by the particles and as result flocs are formed, due to gravity and the particles settles down. Usually coagulation process is carried out in Jar Test apparatus. To assess the ideal dosage of coagulant required for wastewater treatment, a jar test has been utilized. It has six jars with steel paddles which helps for rapid mixing for first 2 to 3 minutes, and then at slow speed for 15 minutes after these process the jars are kept idle for 30 minutes. And noted the settling of sediments is considered to be the optimum dosage of coagulant taken into the study.

**4. Natural Coagulants for High Strength Wastewater Treatment**

Natural coagulants play a significant part in the treatment of high strength wastewater. They are composed of polymers of polysaccharides and amino acids as well as carbohydrates, protein, and lipids. According to research, charge neutralization and polymer bridging are the primary mechanisms underlying coagulation action. Polymer absorption creates polymer bridging [41]. The goal of polymer adsorption is to alter the way surfaces interact, which enhances flocculation procedures, surface characteristics, and particle dispersion. Most frequently, it is determined by how quickly a solution loses concentration after coming into contact with a surface [41].

**4.1 Dye Industry**

Synthetic dye colors are created using dyes such as dispersed dyes 218 and dispersed navy 35, basic orange 37, and basic red 1. During this procedure, the dye colors are dissolved in water and used for coloring purposes, with the leftover wastewater being released as effluent. [3]. The application of natural coagulant derived from various plants and animals has more advantages than other in the treatment of wastewater. The pH of the treated water is not changed by the natural coagulant. The majority of all-natural coagulants, such as banana peel powder, neem seed powder, papaya seed powder, and peanut powder, are used to treat wastewater from the dairy industry. Neem seed powder has been found to be effective for treating wastewater from the dye industry, with a 90% reduction in COD from the initial level of 1486 mg/l to 563 mg/l. sewage with a pH of 7.32 [1].

The roots of Alcearosea (hollyhocks) were naturally dried, and 2.5 g of the powdered root was put to 100 ml of 0.5 M sodium chloride that had been produced with distilled water and filtered through a mesh made of cloth. The resulting milky mucilage was then removed and utilized as a coagent. The most effective way to remove disperse dyes from aqueous solutions and sewage is with alcearosea coagulant [2].

Moringa oleifera seed is allowed to dry in the broiler for 24 hours at a temperature of 50°C, then it grinded into a medium fine powder by using residential blender , the seed of Tamarina indica were collected from the kitchen as waste material is dried for one hour at 110 oC in an air broiler, then crushed in a four mill, strychonospotatorum (Nirmali) seed was gathered and soaked in water along with 2 ml of conc HCL due to their hard structure and followed for 7 days, then blended to make into soup like arrangement and filter through nylon fabric ,these material is dried in 24h at 103 to 105 oC, among the three seeds, M. oliefera has a better capacity for the reduction of TDS and TSS, BOD and COD, and Tamarind has the capacity to lower fluoride concentration. These three seeds are utilized as natural coagulants for the treatment of wastewater. [3].

Canna Indica commonly known as Kalvazhai is used for the industrial wastewater treatment [4] when the industrial effluent is made to pass through Canna Indica which proves to be efficient in removing the increased organic load, colour, and nitrogen compound from the wastewater. The rhizobium of this plant is believed to be responsible for the removal of pollutant [4].Tamarind powder can reduce the turbidity and COD of 97.78% and 43.50%, and the colour removal of 100 %. It also noted that tamarind power has the capacity to reduce fluoride content, tamarind contain phenolic groups that can remove proton from any atom, ion or molecule to produce phenoxide which enhance the effect of coagulation.[4].

The application of Hibiscus seeds as Natural coagulant used to reduce the concentration of turbidity, the natural polyelectrolyte present in the seed in the form of polysaccharide and protein usually exhibit higher molecular weight, the greater increase of surface area increases the adsorption processes and coagulation. Additionally, hibiscus sabdariffa seeds include cationic peptides such glutamic, aspartic, and leucine as well as coagulation protein [5]. Hibiscus sabdariffa flowers are picked, the seeds are removed, and they are cleaned with distilled water. After drying for two hours at 600 C while utilizing this powdered as a natural coagulant, color removal can reach up to 96.67% under ideal conditions. [5].

At pH 4.0 and a coagulant concentration of 25 mg/l, it was discovered that the maximum percentage of Congo red (CR) elimination could be achieved with SSP (Surjana seed powder), Chitosan, and MSP (Maize seed powder), respectively [6]. The seeds of the Plantago major (great plantain) plant were harvested, dried at 1000°C for 2 hours, ground in a grinder, and sieved to a mesh size of 35 (500 m) [7]. The powdered material was then soaked in boiling water containing a 0.9% NaCl solution and stirred for 2 hours before being thoroughly mixed for 10 minutes at 20 rpm. The ideal circumstances of 49.6 minutes, pH 6.5, and 297.6 mg/L coagulant dose were employed to generate this mixed solution, which was used as a natural coagulant to achieve a high color 92.4% and COD 81.6% reduction efficiency [7].

Grape seed were purchased from a nearby store, and grape seed extract was made by first washing the seeds with water, drying them, and then powdering them. 20 cc of a 70% ethanol solution were used to extract 1g of grape seeds overnight in a shaking incubator at 106 rpm and 280C. The extract was again incubated for 10 minutes at 95 0C after being filtered and stored at 40 0C before being added to dye-contaminated water [8]. It is proved that the treatment by using GSE as natural coagulant, toxicity of MG and CV (Malachite green and crystal violet) contamination decreased. Table 1 lists the numerous natural coagulants used to remediate effluent from the dye industry.

**Table 1** Treatment of Dye industries wastewater by using various Natural coagulants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter studied** | **Remark** | **Reference** |
| Coagulation (Jar test) | Banana Peel Powder  Neem seed powder  Papaya seed  Peanut seed powder | pH, Turbidity BOD,COD and Chloride | Among the all, Neem seed powder is more efficient in treating dye wastewater at pH 7.32 and reduces C.O.D. values by 90%. | [1] |
| Coagulation | Alcearosea root mucilage | Red 60 dye and reactive blue 19 dye are dispersed | The best method for removing dyes from aqueous solutions and sewage is alcearosea coagulant, especially for disperse colours. | [2] |
| Coagulation | Moringa oleifera,  TamarinaIndica and Strychonomouspotatorum | pH, Turbidity, TSS,  TDS,BOD,COD | Between the two characteristics, M. oliefera has a stronger ability for the expulsion of TDS and TSS, BOD and COD, and it has a more effective method for treating coloring manating.  Tamarin have the capacity of reduce fluoride. | [3] |
| Coagulation | Canna Indica (KalVazhai) and Tamarind | Turbidity, COD | Turbidity and COD are removed with 97.78%, 97.01%, 43.50%, and 24.86%, respectively. | [4] |
| Coagulation | Hibiscus sabdariffa seeds | Dye Concentration | A 96.67% dye clearance rate is possible with the best conditions. | [5] |
| Coagulation | Maize seed powder (MSP), Chitosan, and Surjana seed powder (SSP) | Sludge Volume Index (SVI), pH, coagulant dose, flocculation period, and turbidity | At pH 4.0 and a coagulant dose of 25 mg/l, the highest percentage (congo Red) elimination was determined to be 98.0, 94.5 and 89.4% for SSP, Chitosan, and MSP respectively. | [6] |
| Coagulation | Plantago major | pH , coagulant dose , colour and COD reduction | P. majorL. was used to achieve high color 92.4% and COD 81.6% reduction efficiency at the ideal circumstances of 49.6 min, pH 6.5, and 297.6 mg/L coagulant dosage. | [7] |
| Coagulation | Grape seed extract | Malachite green and crystal violet | The toxicity of MG and CV contamination was lessened by treatment with natural polyphenols and GSE. | [8] |

**4.2 Dairy Industry**

Massive amount of water is required for the production of dairy industries need, for the production of 1 litre of processed milk 3 litre waste water will be produced [9]. Due to the presence of organic components, the dairy industry's effluent has a high concentration of organic elements such fats, carbohydrates, grease, and proteins as well as a high concentration of TDS, COD, BOD, and turbidity. Orange peels, Neem leaves, Cactus were collected from the local market and surrounding then it is washed in water, dried in sunlight for 4 to 8 days, the grinded power is used as a natural coagulant for the treatment of Dairy wastewater. Among this cactus has the good reduction in 64.65% of Turbidity and 72.60% of COD [9].

Yellow passion fruit and ripe okra (lady’s finger) is collected form a agro-industrial processing waste. The seed of the passion fruit and ripe okra fruit is dried in an oven at a 1500C for 4 hrs and 1100C for 8 hrs respectively. Then it is crushed and sieved through the size of 0.35mm to 0.85mm. Okra dosage of 2.0 g L-1 at pH 9.00 and passion fruit seed dosage of 1.3 g L-1 at pH 5.00 were determined to be the best conditions for eliminating turbidity and COD. Okra as a coagulant reduced turbidity by 91.1% and COD by 48.3%, whilst passion fruit seeds reduced turbidity by 91.5% and COD by 50.3% [10].

Fenugreek and Moringa oleifere seeds were purchased from local markets and farms, then stored for 24 hours in sunlight or an oven before being ground and sieved through a 600 m sieve.Moringa oleifera delivers doses of 0.2gm/l, 0.4gm/l, 0.6gm/l, 0.8gm/l, and 1gm/l. The doses delivered by fenugreek are 1 gm/l, 1.5 gm/l, 2 gm/l, 2.5 gm/l, and 3 gm/l from the optimum dose chosen, which is 0.6 gm/l. From this, 2.5gm/l is the chosen optimal dose. Numerous metrics, including BOD, COD, and turbidity, have been decreased to low levels. Because it contains protein, Moringa oleifera is a more effective coagulant than other coagulants. [11].

Chick pea (Chana) seed were collected and grinded to fine powder, sieved through 600µm, 10 g of this powered is dissolved in 1 litre of distilled water stirred well for 10 minutes and stored in refrigerator at 50C. After 15 days of drying, tamarind seeds are ground into a fine powder that passes through a 600-mesh filter. 2g of this powder is then added to 100 ml of distilled water, and the resulting solution can be used as a natural coagulant in 30 minutes. Tamarind seed and cerarietinum reduce COD by 81.81% and 63.63%, respectively, from the original value of pH, and remove turbidity with respective removal efficiencies of 39.53% and 30.23%. There are 7.42,3 NTU of turbidity, 1826 mg/l of COD, and 400 mg/l of BOD5 correspondingly [12].

Moringa oleifera and Phaseolus Vulgaris (green beans) collected and dried in an oven at 700C, then it is grounded to fine powered by grinder, the powdered is sieved through 600µm. When this powder is employed as a natural coagulant, turbidity is reduced by 78.49%, BOD3 is decreased by 79.64%, COD is decreased by 85.81%, total dissolved solids are decreased by 8.59%, and total suspended solids are increased by 95.45% [13].

Moringa oleifera, Cicer arietinum (chickpea), Dolicus lablab (hyacinth bean), and Trigonella foenum-graecum (fenugreek) all the seed is collected from local market and dried naturally in sunlight, blender used to grind the ingredients through a 600-m, when this powder used as natural coagulant, M.oleifera, Azadirachtaindica T.foenumgraecum, c.arietinum can able to reduce the turbidity by 61.60%, 71.74%, 58.20% and 78.33% respectively[14,16,17]. Acacia mearnsiide (green wattle) is a flowering plant which has high concentration of tannins can be used as a natural coagulant (Tanfloc SG and Tanfloc SH) prepared in concentrations of 1,000 mg.L-1. Tanfloc SG and Tanfloc SH while using as coagulant for the treatment of dairy wastewater can reduce COD 77.28% and 44.14% respectively [15]. M. oleifera, Dolichos lablab, T. foenum-graecum, and Cicerarietinum each have turbidity and COD values of 61.60%, 71.74%, 58.20%, and 78.33%, and 65.0%, 75%, 62.5%, and 83%, respectively. Initial pH, COD, and turbidity values are 7.41, 289.5 NTU, and 10,000 mg/l [17]. Moringa seed is more effective in reducing the % of turbidity at 77% efficiency [18]. In table 2 lists the treatment procedures and natural coagulants used in the treatment of dairy wastewater.

**Table 2** Natural Coagulants Used in the Treatment of Dairy Wastewater

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter** | **Remark** | **Reference** |
| Coagulation (Jar test) | Cactus, Orange peels and Neem leaves | pH, COD, Turbidity and TDS | Among these three natural coagulants Cactus was found most effective. Coagulating with Cactus attained removal of 64.65% Turbidity and 72.60% COD. | [9] |
| Coagulation /dissolved air flotation | Ripe okra (Abelmoschusesculentus) and passion fruit (Passifloraedulis) seeds | pH, Turbidity and COD | Okra as a coagulant reduced turbidity by 91.1% and COD by 48.3%, whilst passion fruit seeds reduced turbidity by 91.5% and COD by 50.3% from the SDW. | [10] |
| Coagulation | Moringa oleifera and Fenugreek | BOD,COD,  Turbidity,  Total solids | Because it contains protein, moringa oleifera is a more effective coagulant than other coagulants. | [11] |
| Coagulation | Tamarind seed and  Cicerarietinum  (Chick Pea) | BOD,COD,  Turbidity,  TS,TSS | Tamarind seed and cicerarietinum had turbidity removal efficiencies of 39.53% and 30.23%, respectively, and COD reduction efficiencies of 81.81% and 63.63%, respectively. | [12] |
| Coagulation | Moringa Oleifera | BOD, COD, turbidity, pH | The decrease in turbidity, BOD3, COD, TDS and TSS is 78.49%, 79.64%, 85.81% 8.59% and 95.45% respectively | [13] |
| Coagulation-flocculation | Moringaoliefera, Azadirachtaindica, Trigonella foenum graecum (fenugreek) and cicer arietinum | BOD, COD, turbidity, pH | The effectiveness of M. oleifera, Azadirachta indica, T. foenum graecum, and C. arietinum in lowering turbidity is 61.60%, 71.74%, 58.20%, and 78.33%, respectively. | [14] |
| Coagulation -flocculation | Tanfloc SG and SH | Turbidity  COD  Total solids  Sludge volume  Total coliform  Thermotolerant coliform | COD elimination with Tanfloc SG coagulant was 77.28%, whereas with Tanfloc SH it was 44.14%. | [15] |
| Coagulation | Cicer Arietinum  (Chick Pea) | BOD, COD TSS and turbidity | The highest percentages of COD and turbidity reduction were discovered to be 58.9% and 86.29%, respectively. | [16] |
| Coagulation | Moringa  Oleifera seeds,  Fenugreek  Dolichos lablab (hyacinth bean) and Cicer arietinum. | BOD, COD, pH and turbidity | M. oleifera, Dolichos lablab, T. foenum-graecum, and Cicerarietinum each have a turbidity reduction efficiency of 61.60%, 71.74%, 58.20%, and 78.33%, respectively. M. oleifera, Dolichos lablab, T. foenum-graecum, and Cicerarietinum all reduce COD with efficiencies of 65.0%, 75%, 62.5%, and 83%, respectively. | [17] |
| Coagulation | Moringa olifera | pH , conductivity,  DO ,turbidity and hardness  metals such as copper, chromium, lead, calcium, magnesium, cobalt and zinc | Moringa seed is more effective than alum with the highest purity in turbidity at 77% efficiency. | [18] |

**4.3 Pharmaceutical Industry**

Pharmaceutical effluent are wastewater is discharged from the pharm industry which contain hazardous waste in nature due to the presence of toxic metals and active pharmaceutical complex compound which does not undergo any degradation processes in nature [21]. Pharmaceutical contamination threatens both human and environmental. One option for treating pharmaceutical wastewater is the coagulation-flocculation process, which uses a natural coagulant. Plant based coagulant is more effective than animal based [19].

The peeled Moringa seeds and Tapioca starch are mashed dried at temperature of 600C and sieved by using 24 mesh size, this sieved moringa powder and tapioca starch was used has natural coagulant by the method of coagulation and flocculation in jar test at 100 rpm for 10 minute. BOD and COD are removed with moringa seed as a coagulant at a rate of 90.12% and 71.23%, respectively. Using tapioca starch as coagulants, 95.25% and 94.63% of BOD and COD were removed. The elimination of BOD and COD was 32% and 31%, respectively, when tiny crab chitosan was used as a coagulant [20].

When paired with either another natural coagulant or an inorganic coagulant in the proper ratios, natural coagulants derived from plants and animals are more successful at treating effluents [21]. Using a composite coagulant made of polyaluminum chloride, M. oleifera seed protein was extracted and described. Fourier Transform Infrared (FTIR) spectroscopy can be used to determine this. Scanning Electron Microscopy (SEM) can be used to compare the morphology of M. oleifera before and after treatment. [22]. Hospital wastewater could be cleaned up by using MOP and MOP-PAC, a composite coagulant made of M. oleifera protein and polyaluminum chloride [22].

Phoenix dactylifera (dates) were collected form farm and dried in sunlight for two weeks after that it is ground using grinder to a particle size of 1.18µm sieve. It has been demonstrated that using this power as a natural coagulant to remove color from wastewater has a maximum color removal effectiveness of 99.86% at a dosage of 100 mg/L [23].

Hibiscus Sabdariffa (Roselle) seed used as a natural coagulant, due to its coagulant properties and Jatropha Curcas contain protein which is used as natural coagulant, Good quality of both seed is collected washed dried in an oven at 600C for 3 hrs then it is crushed into fine powder for using as coagulantIt was discovered that H. Sabdariffa performs best at pH 4 and 190 mg/L of coagulant, removing the largest percentage of turbidity (35.6%) and reducing COD by 29%. [24].

M.oleifera seed were collected from local market dried and converted to fine powdered of size of 600µm.Moringa oleifera seeds removed around 80.0% to 99.5% turbidity and color respectively. BOD and COD reduce to the value of 373 and 5135 mg/lit from 3776 and 13728 mg/lit[25].

**Table 3** Treatment of Pharmaceutical industry wastewater using various Natural Coagulants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter** | **Remark** | **Reference** |
| Coagulation-flocculation | Moringaoleifera, Chitosan, Rice starch, Jatrophacurcas, Watermelon seeds, Banana pith, Ocimumbasilicum(tulsi) | pH, COD ,colour,  TSS,  Turbidity, TOC | Natural coagulants made of plants are less expensive than those made of animals. | [19] |
| Coagulation- flocculation | Moringa seed, tapioca starch coagulants, crab chitosan coagulant | BOD,COD | BOD removal of 90.12% and COD removal of 71.23% are achieved utilizing moringa seed coagulant. BOD and COD removal from tapioca starch was 95.25% and 94.63%, respectively. The elimination of BOD and CODs was 32% and 31%, respectively, when tiny crab chitosan coagulant was used. | [20] |
| Coagulation | Moringaoleifer, Citrulluslanatus (Seed of watermelon), Treculiaafricana (African bread fruit) Phoenix dactylifera  (Date), Zea mays (Corn or maize), Banana peels, Sesamumindicum (Beniseed) | COD, TSS and turbidity, pH | When paired with either another natural coagulant or an inorganic coagulant in the proper ratios, natural coagulants derived from plants and animals are more successful at treating effluents. | [21] |
| Coagulation | Protein-polyaluminum chloride composite coagulant from Moringa oleifera seeds | Turbidity,pH,COD, E-Coli, UV254, V. cholera,  P. aeruginosa | Hospital wastewater contaminants could be successfully removed using MOP and MOP-PAC composite coagulants. | [22] |
| Coagulation-flocculation | Phoenix dactylifera  (dates) | pH, settling time, and coagulant dosage, Colour | At a dosage of 100 mg/L, the highest color removal efficiency is 99.86%. | [23] |
| Coagulation | H. Sabdariffa and  J. Curcas | pH, COD Turbidity | H. Sabdariffa performs best at pH 4 and 190 mg/L of coagulant, removing 35.8% of the greatest amount of turbidity and lowering COD by 29%. | [24] |
| Coagulation | Moringa Oleifera seed | Turbidity, TSS,  TDS ,COD and BOD | Moringaoleifera seeds reduce around 80.0% to 99.5% turbidity and color respectively, BOD and COD reduce to the value of 373 and 5135 mg/lit from 3776 and 13728 mg/lit. | [25] |

**4.4 Textile Industry**

About 200-300 m3 of wastewater are produced by the textile industry for every ton of finished textile product, and the wastewater contains significant levels of pH, BOD, COD, TSS, TDS, hazardous dyes, and other complex compounds [28]. The release of dyes into local bodies without sufficient treatment might result in serious health and environmental problems due to the presence of several dangerous chemicals [27].

Eirchorrnia crassipes (water hyacinth) and Strychnos potatorum (nirmali seeds) were gathered, and the coagulant solution may be created from the seed kernels or the solid residue by applying pressure to the caked seed. This allows the extraction to be collected and used as a natural coagulant. As just the extraction is utilized as a coagulant, it demonstrates that Eirchorrnia crassipes minimizes the volume of sludge formed in the treatment of waste water [26].

Natural coagulant can achieve better result than the other conventional methods in Textile wastewater treatment, the seed of C.fistula were collected and dried under sunlight and then it is grounded into powder. The extraction prepared by using the fine powder with hexane as a solvent in a soxhlet system, by doing so c.fistula seed gum was produced and these can be used as natural coagulant [27].

O.stricta (Cactus) Cladodes were collected, cleaned, and cut into small pieces. It was then dried for 24 hours at 600°C in a hot air oven. The dried strip was then ground into a powder that passed through 0.42 mm. This powder was then suspended in water and filtered through Whatman filter paper of no. 42. At an ideal pH of 10.3, dose of 162.2 mg L-1, O. stricta's filtered solution, which is utilized as a natural coagulant, removes a maximum of 80.2%, 58.4%, and 77.3% of TSS, COD, and color, respectively) [28].

Azadirachta indicia (Neem leaves) were collected, cleaned, and allowed to air dry for four days at room temperature. After that, the dried leaves were crushed, and the powder was sieved using a 75 micron sieve. For the natural coagulation of textile wastewater, sieved powder is employed. Neem leaf powder significantly improves pH, Total Solids, TDS, TSS, EC, Turbidity, COD, BOD, Copper, and Chromium removal [29].

Banana trees that had reached maturity were gathered from the farm, the stem's pith was removed, and the juice was extracted by combining 100 g of the pith with 10 ml of purified water in a mixing grinder. This purified banana pith juice was employed as a natural coagulant after being removed. The amount of suspended particles decreased to 96% when banana stem extract was added to a quarter of the wastewater volume. Wastewater has a lowered hardness value of 66%.The samples' turbidity also dropped from its initial level to 78% [30][33].

Moringa oleifera seed and Tamarindus Indica were collected washed and dried at room temperature for 24 hrs .Using grinder these seed is made into powder, Tamarindus Indiaca seed is coated with HCL before grinding for peel out the skin of the seed [31] The coagulant from Moringa oleifera lowers pH by 35%, turbidity by 48%, total solids by 68%, total dissolved solids by 70%, total suspended solids by 57%, and tamandus by 68%.A coagulant called indica reduces pH by 32%, turbidity by 32%, total solids by 47%, dissolved solids by 48%, and suspended solids by 44% [31].

Okra was collected from the local market, The pods were cleaned, the seeds and excessive fiber were taken out, and then the mucilage was extracted. 100 ml of each extraction were added to 1 g of gum, which was then agitated for 1 hour until the gum had completely swollen [32] and filtered using a 500 stain steel filter. The thick mucilage was gathered and utilized as a coagulant naturally to clean wastewater. Using a small amount of okra mucilage, 3.20 mg L1, it was possible to remove color 93.57%, turbidity 97.24%, and COD 85.69% [32]. The use of several natural coagulants in the treatment of textile wastewater is listed in Table 4.

**Table 4** Using different natural coagulants to treat wastewater from the textile industry

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter** | **Remark** | **Reference** |
| Coagulation | Strychnospotatorum (nirmali seeds), Eirchorrnia crassipes (water hyacinth) | pH, sulphates, chlorides, TS, TSS, TDS, acidity, alkalinity, BOD,COD. | When used to remediate waste water, Eirchorrnia crassipes produces less sludge and is environmentally benign and biodegradable. | [26] |
| Coagulation | Cassia fistula coagulant | pH , Colour removal | C. fistula With a percentage removal of 93.83% at a volume of 30 L and a coagulant dosage of 1.17 mg L1, coagulant is an efficient substance for treating genuine textile wastewater. | [27] |
| Coagulation | Opuntia stricta  (O.stricta) (cactus ) | TSS, COD, and color. | O. stricta gives at an ideal pH of 10.3, a dosage of 162.2 mg L-1 results in a maximum elimination of 80.2%, 58.4%, and 77.3% for TSS, COD, and color, respectively. | [28] |
| Coagulation | Neem leaves powder | pH,  TS,TDS,TSS, EC, Turbidity, Alkanity Iron, silica, COD, BOD, copper, chromium, hardness, chloride, and sulfate | The BOD3/COD ratio of the effluent was improved as a result of the coagulation/flocculation process, according to experimental data, which showed that the wastewater could be efficiently treated. | [29] |
| Coagulation | banana stem  extract | TSS, Turbidity and hardness | 96% of the suspended solids were reduced by banana stem extract. The 66% hardness To 78%, the turbidity dropped. | [30] |
| Coagulation | MoringaOleifera and TamarindusIndica | PH, Turbidity, TS, TDS and TSS | 35% pH, 48% Turbidity, 68% TS, 70% TDS, 57% TSS, and Tamarindus are removed by MO coagulant.The contents of the indica coagulant remove 32% pH, 32% turbidity, 47% TS, 48% TDS, and 44% TSS. | [31] |
| coagulation/  flocculation | Abelmoschus  Esculentus  (okra mucilage) | Turbidity, color, and COD. | Using a small amount of okra mucilage, 3.20 mg L-1, 88.0 mg L-1, a high reduction of color (93.57%), turbidity (97.24%), and COD (85.69%) was achieved. | [32] |
| Coagulation | Banana pith juice | TSS, pH, and turbidity | At pH 4, the percentages of EC, TS, and turbidity removed by the banana stem juice were 50, 50.1, and 97.5%, respectively. | [33] |

**4.5 Tannery Industry**

Tannery wastewater generate a complex mixture of both organic and inorganic components from the various manufacturing processes like preparatory stages, tanning and crusting, in which enormous of wastewater is produced, while processing the preparatory stage generate lot of hazardous waste. Nearly 1 Kg of skin while processing can produce 30-35 litres of wastewater which contain pH, High concentration of TSS, BOD, COD and complex compound [34]. High contamination of chromium salts, phenolic which can affect the both human and Environment. And also tannery waste has strong colour and foul smell due to the presence of high organic compound. Different physical-chemical techniques are employed, including active carbon adsorption, ion exchange, and reverse osmosis, but each has drawbacks that outweigh their benefits [34]. Hence a new method has to adopt which have to treat the wastewater at low cost and with high efficiency.

The seed of Moringaolifera, Sappindusemarginatus (Soup Nut) and strychnospotatorum (Nirmali seed) collected dried and made into powder, These powered can remediate tannery wastewater at concentrations of 0.05g/ml, 0.10g/ml, 0.15g/ml, and 0.20g/ml when used as natural coagulants. The turbidity is reduced to 88% at pH 7 [34].Moringa olifera seed was taken and dried in sunlight then it is made into powder which pass through 75 micron sieve, 20 gm of this powder is mixed in 250ml of distilled water, filtered using filter paper, these filtered water is used as natural coagulant, 76% of colour and odour were removed [35]. Cicer arietinum (Chickpea), Moringa oleifera and cactus obtained from the neighborhood market and the side of the road, dried at 600C for 24 hours. The highest reduction in turbidity was found to be 81.20%, 82.02%, and 78.54%, and the maximum reduction in COD was found to be 90%, 83.33%, and 75%, respectively. The dry materials were ground in a grinder and sieved through 600 m [36].

Azadirachtaindica (Neem Leaves) was collected from road side dried in an oven at 600C for 24 hrs. Then it is ground to fine power and sieved to size 600µm, The percentage of turbidity, COD, BOD, TSS, and TDS removal from this powder employed as a natural coagulant was 85.66%, 80.42%, 96.74%, 84.81%, and 87.06%, respectively [37]. Aloevera leaves were washed to get out the moisture of the leaf then it is made into slice and dried in sunlight for 48 hrs and then this dried leaves again dried at 600C in hot plate for 2 hrs. This aloe vera is crushed in a ball mill at 180 rpm for six hours. Aloevera coagulant's structure and shape were examined using a scanning electron microscope (SEM), which demonstrated that it functions as a natural coagulant [38].

The seed of S. potatorum (Thethankottai)**and**Moringa oleifera **were dried and powdered for a size of 0.05 mm sieve and used as a natural coagulant for wastewater treatment to remove heavy metals, it shows** S.potatorum and M. oleifera in the treatment of tannery effluent was more effective [39].AloeVera, Moringa Oleifera and Cactus were collected and dried ground into power [35][36][38] these dried power when used as coagulant M. Oleifera cactus has the best dosage at 40 mg/l with pH 7, whereas seeds provided the maximum reduction in turbidity and COD at 15 mg/L with pH 6. Aloevera's ideal dosage is 5% concentration, and its ideal pH is 5 [40].

**Table 5** Treatment of Textile industries wastewater using various Natural Coagulants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter** | **Remark** | **Reference** |
| Coagulation and flocculation | Moringaolifera, Strychnos potatorum  Sappindusemarginatus | colour, odour and turbidity | The turbidity of tannery effluent was removed by 88% at pH 7 | [34] |
| Coagulation and flocculation | moringaolifera and lime | TDS, turbidity, odor, color | The transmittance rate rose to 76%. There was no trace of color or smell. Other original parameters were also sharply scaled back. | [35] |
| Coagulation and flocculation | Cicer arietinum, Moringa oleifera, and Cactus | pH,Turbidity,  COD | Moringa oleifera and Cicer aretinum showed the greatest reductions in turbidity (82.02% and 90%, respectively) among the natural coagulants utilized in this study. | [36] |
| coagulation and flocculation | Azadirachta indica leaves powder | turbidity, TSS, TDS, COD and BOD | Azadirachta When indica leaves powder was employed as a coagulant and administered at a dosage of 3 mg/L, it was discovered that turbidity, COD, BOD, TSS, and TDS were removed to a percentage of 85.66%, 80.42%, 96.74%, 84.81%, and 87.06%, respectively. | [37] |
| coagulation and flocculation | aloevera leaf | Turbidity, hardness, chlorides, total solids, total suspended solids, BOD, and COD. | SEM analysis of the structure and morphology of aloevera coagulant reveals an amorphous nature and rather porous matrix that permits inter-particle bridging. | [38] |
| Coagulation | S. potatorum**and**  M. oleifera**seeds powder** | pH, TDS, TSS, Total Hardness Cr3-, Mg, Fe, P, COD, BOD | S. potatorum and M. oleifera in the treatment of tannery effluent was more effective. | [39] |
| Coagulation | AloeVera, Moringa Oleifera and Cactus | COD and turbidity | M. Oleifera, the supplied samples, seeds removed the most turbidity and COD. The ideal pH for M. oleifera is 6, and the recommended dosage is 15 mg/l. The ideal dosage for cactus is 40mg/l, and its pH should be 7. Similar to this, aloe vera's ideal dosage at 5% concentration and pH 5 is similar. | [40] |

**Conclusion**

Due to the presence of large concentrations of turbidity, TDS, TSS, COD, BOD, and other complex compounds, the removal of contaminants from different industrial wastewaters is difficult. According to several studies, employing natural coagulants to treat wastewater results in the highest levels of efficacy at the lowest possible cost, with the least amount of sludge generation. This review analyzed numerous papers on industrial wastewater treatment by using natural coagulant, like Seed, leaves, mucilage, root and flower form various plant and tree is derived as Natural coagulant, MoringaOleifera (drumstick) seed, Azadirachtaindica (Neem) leaves, Sappindusemarginatus (SoupNut), strychnospotatorum (Nirmali) seed, AloeVera leaves okra, (Lady’s Finger) seed, Eirchorrnia crassipes (water hyacinth)leaves, Phoenix dactylifera (dates) seed and H. Sabdariffa seed are used as natural coagualts in the treatment of wastewater. MoringaOleifera and Azadirachtaindica (Neem) has place major role in the reduction of high strength concentration like pH, TSS,TDS,COD,BOD, Copper and Chromium present in the in the industrial wastewater. The sludge produce from this process can be used as fertilizer for plant cultivation as it contain more organic content and it is Eco-friendly to the Environment.

**References**

[1] P. Sasirekha, M. Sasi Kumar, R. Siva Shankar, S. Vignesh Alias Shangesh “Treatment of Dye Waste water by using Natural Coagulants” International Journal of Emerging science and Engineering International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, Volume-6 Issue-3.

[2] TaherehZarei Mahmoudabadi, Parvaneh Talebi and MahrokhJalili “Removing Disperse red 60 and Reactiveblue 19 dyes removal by using Alcearosearootmucilage as a natural coagulant” Springer (2019) 9:113.

[3] Dr.A.Mani,T.P.Meikandaan,P.G.Gowrishankar,Dr.T.E. Kanchanabhan “A study on treatment of industrial effluent (Dying) using Moringaoleifera, TamarinIndica as coagulant” International Journal of Civil Engineering and Technology (IJCIET) Volume 10, Issue 01.

[4] M. Mathuram, R. Meera, G. Vijayaraghavan “Application of Locally Sourced Plants as Natural CoagulantsFor Dye Removal from Wastewater: A Review” Journal of materials and Environmental science Volume 9, Issue 7, Page 2058-2070.

[5] Ho Nicholas JianHoong ,NurhazwaniIsmail “Removal of Dye in Wastewater by Adsorption-Coagulation Combined System with Hibiscus sabdariffa as the Coagulant” MATEC Web of Conferences 152, 01008 (2018).

[6] Himanshu Patel, R.T. Vashi “Removal of Congo Red dye from its aqueous solution using natural coagulants” Journal of Saudi Chemical Society (2012) 16, 131–136.

[7] Naz Chaibakhsh, NedaAhmadi, Mohammad Ali Zanjanchi “ Use of Plantago major L. as a natural coagulant for optimized decolorization of dye-containing wastewater” Industrial Crops and Products 61 (2014) 169–175.

[8] Jong-Rok Jeon, Eun-Ju Kim, Young-Mo Kim, Kumarasamy Murugesan, Jae-Hwan Kim, Yoon-Seok Chang “ Use of grape seed and its natural polyphenol extracts as a natural organiccoagulant for removal of cationic dyes” Chemosphere 77 (2009) 1090–1098.

[9] Ami. N. Dave ,Ankit Hadiya,Prachi Joshi,Patel Mittal,PiparotarUrvisha,PrajapatiPiyush “Use of Natural Coagulant for Dairy Wastewater Treatment” International Research Journal of Engineering and Technology (IRJET) Volume: 07 Issue: 06.

[10] Gustavo Lopes Muniz,, AlissonCarraro Borges, Teresa Cristina Fonseca da Silva “ Performance of natural coagulants obtained from agro-industrial wastes in dairy wastewater treatment using dissolved air flotation” Journal of Water Process Engineering 37 (2020) 101453.

[11] Pramod D. Sutar, Shrikant M. Bhosale “Use of natural Coagulants for Pre-treatment of Dairy Waste Water” International Journal for Research in Engineering Application & Management (IJREAM) ISSN : 2454-9150 Vol-04, Issue-05.

[12] Shivam B. Magar, Dr. M.V Jadhav “Use of Herbal coagulants for treatment of dairy waste water” International Journal for Research Trends and Innovation Volume 3, Issue 12 | ISSN: 2456-3315.

[13] Neethu.P, Navami.D, Anitha.K(2017)” Treatment of Dairy Wastewater By Moringa Oleifera as Natural Coagulant” IJARIIE-ISSN(O)-2395-4396 Vol-3 Issue-4.

[14] L.Gayathri “Treatment Of Dairy Wastewater By Using Natural Coagulants” International Research Journal of Engineering Sciences Volume 3 Issue 2.

[15] Gabriele Wolf, Roselene Maria Schneider, Milene Carvalho Bongiovani, Eduardo Morgan Uliana, Adriana Garcia do Amaral “Application of Coagulation/Flocculation Process of Dairy Wastewater from Conventional Treatment Using Natural Coagulant for Reuse” Chemical Engineering Transactions Volume. 43,2015.

[16] LailaJaseela A, Dr Mohandas Chadaga “Treatment of Dairy Effluent Using CicerArietinum” International Journal of Innovative Research in Science, Engineering and Technology Vol. 4, Issue 6, June 2015.

[17] Chidanand Patil, ManikaHugar “Treatment of dairy wastewater by natural coagulants” International Research Journal of Engineering and Technology Volume: 02 Issue: 04.

[18] Vikash R. Agrawal1, Prashant T. Dhorabe, Pratiksha P. Shastrakar, Abhinav R. Khanorkar, Pooja M. Chandrawanshi, Bomblesh P. Kamdi, Sandeep S. Tiwari “Coagulation Of Dairy Waste Water By Using Natural Coagulants”National Conference on "Recent Advances in Engineering and Technology" SAMMANTRANA 19 Organized by Government College of Engineering, Nagpur International Journal of Innovations in Engineering and Science, Vol 4 No.8, 2019.

[19] Motasem Y. D. Alazaiza , Ahmed Albahnasawi , Gomaa A. M. Ali , Mohammed J. K. Bashir,DiaEddinNassani , Tahra Al Maskari , Salem S. Abu Amr and Mohammed Shadi S. Abujazar “ Application of Natural Coagulants for Pharmaceutical Removal from Water and Wastewater: A Review” Water (MDPI) Water 2022, 14, 140.

[20] Agustin Maharani Z.P1,Dwi Setiawan, ErlindaNingsih “Comparison of the Effectiveness of Natural Coagulant Performance on% BOD Removal and% COD Removal in Pharmaceutical Industry Waste”Journal of applied Industrial Engineering-University of PGRI AdiBuanaVol. 04, No.1, 2021.

[21] Ifeoma Maryrose Odika, Chinenye Gloria Nwansiobi, Njideka Veronica Nwankwo,Chiagozie Michael Ekwunife, Uchechukwu Michael Onuoha “A Review on Treatment Efficiency of Pharmaceutical Effluents Using Natural Coagulants” International Journal of Environmental Chemistry 2020; 4(2): 54-61.

[22] Odilon M. Nonfodji, Jacques K. Fatombi , Théodora A. Ahoyo, Sèmiyou A. Osseni,TaofikiAminou, “ Performance of Moringaoleifera seeds protein and Moringaoleifera seeds protein-polyaluminum chloride composite coagulant in removing organic matter and antibiotic resistant bacteria from hospital wastewater” Journal of Water Process Engineering 33 (2020) 101103.

[23] IfeomaMaryjaneIloamaeke and ChizaramOnyinyechi Julius “Treatment of Pharmaceutical Effluent Using Seed Of Phoenix DactyliferaAs A Natural Coagulant” Journal of Basic Physical Research ISSN: 2141-8403 Vol.9, No.1 pp. 91- 100.

[24] Sheena Sibartie, and NurhazwaniIsmail “Potential of Hibiscus Sabdariffaand JatrophaCurcasas Natural Coagulants in the Treatment of Pharmaceutical Wastewater” MATEC Web of Conferences 152, 01009 (2018).

[25] NiteshParmar, J.K. Srivastava “Treatment of Pharmaceutical Waste Water by Coagulation Process Using MoringaOleifera as a Natural Coagulant” International Conference on Recent Advances in Interdisciplinary Trends in Engineering & Applications SSRN-ELSEVIER (2018-19).

[26] G. Prabhakaran , M. Manikandan , M. Boopathi “ Treatment of textile effluents by using natural coagulants” Elsevier Materials Today: Proceedings 2020.

[27] Minh-Trung Dao , Vo-Chau-Ngan Nguyen , Thanh-NhaTran,Xuan-Du Nguyen ,Duc-Thuong Vo ,Van-Kieu Nguyen ,and Le-Thuy-Thuy-Trang Hoang(2021)” Pilot-Scale Study of Real Domestic Textile Wastewater Treatment Using Cassia fistula Seed-Derived Coagulant” Journal of Chemistry Volume 2021, Article ID 7608856.

[28] GhulamHussain and SajjadHaydar “Textile Effluent Treatment Using Natural Coagulant Opuntia strictain Comparison with Alum” Clean – Soil, Air, Water 2021, 2000342.

[29] S. Mohan1, K.Vidhya, C.T. Sivakumar, M.Sugnathi, V. Shanmugavadivu, M.Devi “Textile Waste Water Treatment by Using Natural Coagulant (Neem-Azadirachta India)” International Research Journal of Multidisciplinary Technovation /2019, 1(6), 636-642.

[30] Anupriya J, NaufalRizwan P S, JansiSheela S, MuthuPrema K , ChellaGifta “Waste Water Treatment Using Banana Stem Extract From Textile Industries” International Journal of Applied Environmental Sciences ISSN 0973-6077 Volume 13, Number 1 (2018), pp. 105-119.

[31] S.Ramesh, L.Mekala “Treatment of Textile Waste Water Using MoringaOleifera and TamarindusIndica” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 03.

[32] T.K.F.S. Freitas, V.M. Oliveira, M.T.F. de Souza, H.C.L. Geraldinoa, V.C. Almeida,S.L. Fávarob, J.C. Garcia “ Optimization of coagulation-flocculation process for treatment ofindustrial textile wastewater using okra (A. esculentus) mucilage asnatural coagulant” Industrial Crops and Products 76 (2015) 538–544.

[33] Gopika G.L and K.MophinKani “ Accessing the Suitability of Using Banana Pith Juice as a Natural Coagulant for Textile Wastewater Treatment” International Journal of Scientific & Engineering Research, Volume 7, Issue 4, April-2016 ISSN 2229-5518

[34] LalithVaradhan S and Mohan S(2017)”Plant Seed Flocculants: A Novel Physico-Chemical Approach for The Removal of Colour, Odour And Turbidity From tannery Effluent” International Journal of Current Advanced Research Volume 6; Issue 3; March 2017.

[35] Gobinath.R, S.Aravind, AshiSudhakar.P.K, A.Sathya Singh, M.Swathi (2013)” Color and odor removal from tannery waste water using natural coagulant andlocally available commercial grade lime” Scholars Journal of Engineering and Technology 1(3):133-139.

[36] TasneembanoKazi ,ArjunVirupakshi(2013)” Treatment of Tannery Wastewater Using Natural Coagulants” International Journal of Innovative Research in Science,Engineering and Technology Vol. 2, Issue 8.

[37] Dr. N. Muralimohan, S. Augustin, G. Meiyazhagan, P. Sethupathi, V. Ramesh(2017) International Journal of Environment, Agriculture and Biotechnology (IJEAB) Vol-2, Issue-2, M ar-Apr- 2017.

[38] A. ShaheenFathima, R. Bhuvaneswari and J. Jeyanthi(2020)” Characterization of Tannery Effluent and Synthesis of Natural Coagulant” AIP Conference Proceedings 2270, 060003 (2020).

[39] S.A. Kamala SankariMadhavan and S. Karpagam(2019)”Natural Coagualnt :An Easy way to remove Heavy Metals from Tannery Effluent”[Journal of Industrial Pollution Control](https://www.icontrolpollution.com/ArchiveICP/currentissue-industrial-pollution-control.php) 35(1)(2019) pp 2266-2270.

[40] L Muruganandam, M P Saravana Kumar, Amarjit Jena, Sudiv Gulla and Bhagesh

[41] Godhwani” Treatment of waste water by coagulation and flocculation using biomaterials” IOP Conf. Series Materials Science and Engineering 263 (2017) 032006.

[42] S. Nimesha, C. Hewawasam, D.J. Jayasanka, Y. Murakami, N. Araki, N. Maharjan “Effectiveness of natural coagulants in water and wastewater treatment” Global Journal of Environmental Science and Management” 8(1): 1-16, 2022.