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

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**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. Natural coagulants such as Banana Peel Powder, Neem seed powder, Papaya seed, Peanut seed powder, Moringa oleifera (drumstick) seed powder and Grape seed extract used as a natural coagulant to treat the high strength concentration wastewater.

**2. Coagulants**

Coagulants can be classified as Natural and Chemical coagulants. Natural coagulants are coagulants derived from Natural Environmental plants and animals. Chemical coagulants manufactured by using some chemicals like (Aluminium sulphate, Ferric sulphate, and Ferric chloride and Poly aluminum chloride).There are three types of Natural coagulants, plant based, animal based and microorganism based. Plant based coagulant are derived from flower, seed, leaves, stem, bark, root and resin gums of plants and trees. Animal based coagulant is derived from Chitosan shells of crabs, lobsters, shrimps, diatoms, fungi, insects, freshwater and marine sponges, and mollusks [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. Jar test has been used to determine the optimum dosage of coagulant needed for wastewater treatment. 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 in Treatment of High Strength wastewater**

Natural coagulants place a major role in treatment of high strength wastewater, Natural coagulant contain carbohydrates, protein, and lipids and has polymer of polysaccharides and amino acids. Based on the studies the main mechanism of coagulation activity is charge neutralization and polymer bridging [41]. Polymer bridging is formed by polymer adsorption.The purpose of polymer adsorption is to modify the interaction between the surfaces, which in turn improves the dispersion of particles, flocculation processes, and surface properties. It is most commonly measured through the concentration depletion of a solution after being in contact with the surface [41].

**4.1 Dye Industry**

Dyes like, dispersed dyes 218 and disperse navy 35,basic orange 37 and basic red 1 are used to prepare synthetic dye colours, during this process, dye colours dissolved in water and used for colouring purpose, and the remaining wastewater discharged 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 natural coagulant does not alter the pH of the treated water [1] mostly natural coagulants like Banana peel powder, Neem seed power, papaya seed powder and peanut power is used for the treatment of dairy industry wastewater, among the all-natural coagulant, Neem seed powder has 90% reduction in COD from initial level 1486mg/l to 563 mg/l and it is found to be effective for treatment of dye industry Wastewater at pH 7.32 [1].

Alcearosea (hollyhocks) root were naturally dried,2.5 g of dried root powder was added to 100 ml of 0.5 M sodium chloride which was prepared with distilled water and filter through mesh made up of fabric filter ,these extracted milky mucilage is used as coagualnt. Alcearosea coagulant has the best ability in removing especially Disperse dyes from aqueous solutions and sewage [2].

Moringa oleifera seed is permitted to dry in the broiler at a temperature of 50oC for 24 hrs, 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 in air broiler at 110oC for 1 hr and crushed in 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, then it is used as natural coagulants for the treatment of wastewater, among the three seeds, M.oliefera has greater capacity for the reduction of TDS and TSS BOD and COD and Tamarind have the capacity of reduce fluoride concentration [3].

Canna Indica commonly known as Kalvazhai is used in the treatment of industrial wastewater [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 coagulation and adsorption processes. Hibiscus sabdariffa seed also contain coagulation protein, like cationic peptides, such as glutamic acid, aspartic acid and leucine [5]. Hibiscus sabdariffa flower are collected and the seeds are removed and washed by using distilled water and then it is dried in an oven at 600C for 2 hrs , by using this powdered as natural coagulant, dye removal reaches up to 96.67% under optimum parameters [5].

The maximum percentage of Congo red (CR) removal was found to be 98.0, 94.5 and 89.4% by using SSP (Surjana seed powder), Chitosan and MSP (Maize seed powder), respectively, at pH 4.0, coagulant dose of 25 mg/l [6]. The seed of Plantago major (great plantain) plant were brought and dried in an oven at 1000C for 2 hrs and then ground in a grinder and sieved to mesh size of 35 (500 µm) these powdered material was soaked in boiling water with 0.9% NaCl solution and stirred for 2h and then mixed thoroughly for 10 min at 20 rpm [7]. This mixed solution used as Natural Coagulant to achieve a high color 92.4% and COD 81.6% reduction efficiency was obtained at the optimal conditions of 49.6 min, pH 6.5 and 297.6 mg/L coagulant dose [7].

Grape seed were obtained from local market, grape seed Extract was prepared by washing the seeds with water and then dried, powdered at room temperature. The grape seeds 1g was extracted overnight with 20 ml of 70% ethanol solution in a shaking incubator at 106 rpm at 280C. Then these extract was filter and stored at 40C, again the extract was incubated for 10 min at 95 0C before adding 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. The treatment of dye industries wastewater by using various natural coagulants is listed in the Table1.

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter studied** | **Remark** | **Reference** |
| Coagulation (Jar test) | Banana Peel PowderNeem seed powderPapaya seedPeanut seed powder | pH, Turbidity BOD,COD and Chloride | Among the all, neem seed powder has 90% reduction in the value of C.O.D and it is more effective for treatment of dye wastewater, at pH 7.32, | [1] |
| Coagulation | Alcearosea root mucilage | Disperse red 60 and Reactiveblue 19 dyes | Alcearosea coagulant has the best ability in removing dyes from aqueous solutions and sewage, especially Disperse dyes. | [2] |
| Coagulation | Moringa oleifera, TamarinaIndica and Strychonomouspotatorum | pH, Turbidity, TSS,TDS,BOD,COD | M.oliefera has greater capacity for the expulsion of TDS and TSS BOD and COD and promising expulsion productivity among the two characteristics and it has better treatment for colouring manating.Tamarin have the capacity of reduce fluoride. | [3] |
| Coagulation | Canna Indica (KalVazhai) and Tamarind | Turbidity, COD | Removal of Turbidity and COD is 97.78%, 97.01% and 43.50% and 24.86% respectively. | [4] |
| Coagulation | Hibiscus sabdariffa seeds | Dye Concentration | dye removal reaches up to 96.67% under optimum parameters.  | [5] |
| Coagulation | Surjana seed powder (SSP), Maize seed powder (MSP)and Chitosan | pH, coagulantdose, flocculation time, Sludge Volume Index (SVI) and turbidity | The maximumpercentage (congo Red) removal was found to be 98.0, 94.5 and 89.4% for SSP, Chitosan and MSP, respectively, at pH 4.0, coagulant dose of 25 mg/l. | [6] |
| Coagulation | Plantago major | pH , coagulant dose , colour and COD reduction | High color 92.4% and COD 81.6% reduction efficiency was obtained using P. majorL. at the optimal conditions of 49.6 min, pH 6.5 and 297.6 mg/L coagulant dose | [7] |
| Coagulation | Grape seed extract | Malachite green and crystal violet | The treatment by natural polyphenols and GSE decreased toxicity of MG and CV contamination. | [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].Effluent from dairy industry has high concentration of organic materials such as fats, carbohydrate, grease, proteins, due to the presence of organic compounds, 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. The optimum conditions found for removing turbidity and COD were, okra dosage of 2.0 g L−1 at pH 9.00, and passion fruit seeds dosage of 1.3 g L−1 at pH 5.00. Okra as coagulant reduced 91.1 % of turbidity and 48.3 % of COD, whereas passion fruit seeds reduced 91.5 % of turbidity and 50.3 % of COD [10].

Fenugreek seed and Moringa oleifere seed were collected form farms and local market and kept in sunlight or in an oven for 24 hrs grinded by domestic mixture and sieved through 600 µm sieve.The doses given by Moringa oleifera are 0.2gm/l, 0.4gm/l, 0.6gm/l, 0.8gm/l and 1gm/l. From this optimum dose selected is 0.6gm/l, the doses given by Fenugreek are 1 gm/l, 1.5 gm/l, 2 gm/l, 2.5 gm/l and 3 gm/l. From this optimum dose selected is 2.5gm/l. The reduction of various parameters like BOD, COD, and Turbidity is reduced to low level. Moringa oleifera is more efficient than other coagulants as it contains protein [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. Tamarind seed is dried for 15 days, grinded and sieved to fine powder pass through 600µm and 2g of this powder is added to 100 ml distilled water, this solution can be used as natural coagulant after 30 minutes. The removal efficiency of turbidity by Tamarind seed and Cicerarietinum are 39.53 % and 30.23 % respectively and the reduction of COD by Tamarind seed and Cicerarietinum are 81.81% and 63.63% respectively from the initial value of pH, Turbidity, COD and BOD5 are 7.42,3 NTU, 1826 mg/l, 400 mg/L respectively [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 these powdered is used as natural coagulant the reduction of turbidity is 78.49%, reduction in BOD3 is 79.64%, reduction in COD is 85.81%, total dissolved solids is 8.59% and total suspended solids is 95.45% [13].

Moringa oleifera, Trigonella foenum-graecum(Fenugreek),Dolicus lablab(Hyacinth bean) and Cicer arietinum (Chickpea) all the seed is collected from local market and dried naturally in sunlight then ground to fine powder by using blender which passing through 600µm, 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].The turbidity and COD by M.oleifera, Dolichos lablab, T.foenum-graecum and Cicerarietinum are 61.60%, 71.74%, 58.20% and 78.33% and 65.0%, 75%, 62.5% and 83% respectively. The initial pH Turbidity, COD are 7.41. 289.5 NTU, 10000 mg/l [17]. Moringa seed is more effective in reducing the % of turbidity at 77% efficiency [18]. The treatment methods and natural coagulant using in the treatment of dairy wastewater is listed in the Table 2.

 **Table 2** Treatment of Dairy wastewater using various Natural Coagulants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 coagulant reduced 91.1 % of turbidity and 48.3 % of COD, whereas passion fruit seeds reduced 91.5 % of turbidity and 50.3 % of COD from the SDW.  | [10] |
| Coagulation | Moringa oleifera and Fenugreek | BOD,COD,Turbidity,Total solids | Moringa oleifera is more efficient than other coagulants as it contains protein. | [11] |
| Coagulation | Tamarind seed andCicerarietinum(Chick Pea) | BOD,COD,Turbidity,TS,TSS | The removal efficiency of turbidity by Tamarind seed and Cicerarietinum are 39.53 % and 30.23 % respectively and the reduction of COD by Tamarind seed and Cicerarietinum are 81.81% and 63.63% respectively. | [12] |
| Coagulation | Moringa Oleifera | BOD, COD, pH and turbidity | The reduction of 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, pH andturbidity | The efficiency of reducing of turbidity by M.oleifera, Azadirachtaindica,T.foenumgraecum, c.arietinumare 61.60%, 71.74%, 58.20% and 78.33% respectively. | [14] |
| Coagulation -flocculation | Tanfloc SG and SH | TurbidityCODTotal solidsSludge volumeTotal coliformThermotolerant coliform | By using Tanfloc SG coagulant, COD removal was 77.28 %, and for Tanfloc SH was 44.14 %. | [15] |
| Coagulation | Cicer Arietinum (Chick Pea) | BOD, COD TSS and turbidity | The maximum reduction in COD and turbidity were found to be 58.9% and 86.29% respectively. | [16] |
| Coagulation | MoringaOleifera seeds, Fenugreek Dolichos lablab (hyacinth bean) and Cicer arietinum. | BOD, COD, pH and turbidity | The efficiency of reduction of turbidity by M.oleifera, Dolichos lablab, T.foenum-graecum and Cicerarietinum are 61.60%, 71.74%, 58.20% and 78.33%respectively. The efficiency of reduction of COD by M.oleifera, Dolichos lablab, T.foenum-graecum and Cicerarietinum are 65.0%, 75%, 62.5% and 83% respectively. | [17] |
| Coagulation | Moringa olifera  | pH , conductivity,DO ,turbidity and hardnessmetals 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. The Coagulation –flocculation method is one of the solutions for the treatment of pharmaceutical wastewater by using 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. By using moringa seed as coagulant, removal of BOD and COD are 90.12% and 71.23% respectively. Using tapioca starch as coagulants, % removal of BOD and COD was 95.25% and 94.63%. The use of small crab chitosan as coagulant showed % removal of both BOD and COD was 32% and 31% [20].

Natural coagulants from plants and animal origins are more effective in treating effluents when combined with either another natural coagulant or inorganic coagulant in appropriate ratios [21]. M.oleifera seeds protein extracted with polyaluminum chloride composite coagulant characterized by some analytical methods. This can be determined by Fourier Transform Infrared (FTIR) spectroscopy. Morphology characteristic of M.oleifera before and after treatment can be studied by Scanning Electron Microscopy (SEM) [22].MOP and MOP-PAC (M.oleifera protein and polyaluminum chloride composite coagulant could be successfully used as coagulant for removing the pollutants from hospital wastewater [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. This powered is used as natural coagulant for the removal of colour in the wastewater, it is proved that the maximum colour removal efficiency is 99.86% at the dosage of 100 mg/L [23].

Hibiscus Sabdariffa (Roselle) seed can be 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 coagulant. It was found that H. Sabdariffa works best at pH 4 and at a coagulant dosage of 190 mg/L with a highest turbidity removal of 35.8% and a reduction of 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 |  Plant-based natural coagulants are more affordable than animal-based ones. | [19] |
| Coagulation- flocculation | Moringa seed, tapioca starch coagulants, crab chitosan coagulant | BOD,COD | By using moringa seed coagulant removal of BOD of 90.12% and COD is 71.23%. Tapioca starch removal of BOD, COD was 95.25% and 94.63%. The use of small crab chitosan coagulant showed removal of both BOD and COD’s was 32% and 31%. | [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 | natural coagulants from plants and animal origins are more effective in treating effluents when combined with either another natural coagulant or inorganic coagulant in appropriate ratios | [21] |
| Coagulation | Moringaoleifera seeds protein-polyaluminum chloride composite coagulant | Turbidity,pH,COD,E-Coli, UV254, V. cholera, P. aeruginosa | MOP and MOP-PAC composite coagulant could be successfully used as coagulant for removing the pollutants from hospital wastewater. | [22] |
| Coagulation-flocculation | Phoenix dactylifera(dates) | pH, settling time and dosage of the coagulant, Colour | The maximum colour removal efficiency is 99.86% at the dosage of 100 mg/L | [23] |
| Coagulation | H. Sabdariffa and J. Curcas | pH, COD Turbidity | H. Sabdariffa works best at pH 4 and at a coagulant dosage of 190 mg/L with a highest turbidity removal of 35.8% and a reduction of 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**

Textile industries generate enormous qualities of highly polluted and toxic effluent, about 200-300 m3 of wastewater is generated per ton of finished textile product, Textile industries wastewater contain high level of pH, BOD, COD, TSS, TDS, toxic dyes and other complex compound [28].due to the presence of numerous hazardous chemical discharge of dyes into local bodies without proper treatment can cause significant health and environmental issues [27].

Strychnos potatorum (nirmali seeds), Eirchorrnia crassipes (water hyacinth) were collected and the coagulant solution may be prepared by either seed kernels or the solid residue by using pressure the seed made into cake by doing so the extraction can be collected and used as natural coagulant. It shows that Eirchorrnia crassipes reduces the volume of sludge produced in the treatment of waste water [26] as only the extraction is used as coagulant.

Natural coagulant can achieve better result than the other conventional methods in the treatment of Textile wastewater, 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].

 Cladodes of O.stricta (Cactus) were collected washed and chopped into small pieces and then it is dried in an hot air oven at 600C, for 24 hrs, after this processes the dried strip is grinded into powder which passing through 0.42 mm, this powder was suspended in water and filter through whatman filter paper of no 42. The filtered solution used as a natural coagulant, O. stricta gives a maximum removal of 80.2%, 58.4%, and 77.3% for TSS, COD, and colour, respectively at optimum pH 10.3,dose 162.2 mg L−1)[28].

Azadirachta indicia (Neem leaves) were collected and washed dried at room temperature for 4 days, then this dried leaves were crushed and the powder is sieved through 75 micron sieve. Sieved powder is used as a natural coagulant for the treatment of Textile wastewater. Neem leaves powder plays a major role for the better removal of pH, Total solids, TDS, TSS, EC, turbidity, COD, BOD, Copper and Chromium [29].

Matured banana plants were collected from the farm and the pith of the stem was separated from the matured plant and the juice was collected by taking 100 g of pith grinded in 10 ml of distilled water using mixing grinder. This extracted banana pith juice filtered and used as a natural coagulant. When banana stem extract is added to 1/4th of the volume of the wastewater the amount of suspended solids reduced to percentage of 96%.The hardness value of wastewater is reduced to 66%.The turbidity of the samples also decreased to 78% from the initial level [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] Moringa oleifera coagulant reduce 35% pH, 48% Turbidity, 68% Total Solids, 70% Total Dissolved Solids, 57% Total Suspended Solids and TamarindusIndica coagulant reduce 32% pH, 32% Turbidity, 47% Total Solids, 48% Total Dissolved Solids, 44% Total Suspended Solids[31].

Okra was collected from the local market, to extract the mucilage, the pods were cleaned, seeds and excess fibre were removed. About 1 gm of gum was soaked in 100 ml of each extraction and stirred for 1 hr where the gum was completely swelled [32] and filter through 500µ stain steel filter. The viscous mucilage was collected and used as natural coagulant for treatment of wastewater. A removal of color 93.57%, turbidity 97.24%, COD 85.69% was obtained using a low amount of the okra mucilage, 3.20 mg L−1[32].the treatment of textile wastewater by using various natural coagulant is listed in Table 4.

**Table 4** Treatment of Textile industries wastewater using various Natural Coagulants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter** | **Remark** | **Reference** |
| Coagulation | Strychnospotatorum (nirmali seeds), Eirchorrnia crassipes (water hyacinth) | pH, sulphates, chlorides, TS, TSS, TDS, acidity, alkalinity, BOD,COD. | The use of Eirchorrnia crassipes reduces the volume of sludge produced in the treatment of waste water , it is eco –friendly and biodegradable | [26] |
| Coagulation | Cassia fistula coagulant | pH , Colour removal | C. fistula coagulant is an effective material for real textile wastewater treatment, percentage removal of 93.83% at a volume of 30 L and a coagulant dosage of 1.17 mg·L−1 .  | [27] |
| Coagulation | Opuntia stricta(O.stricta) (cactus ) | TSS, COD, and color. | O. stricta gives a maximum removal of 80.2%, 58.4%, and 77.3% for TSS, COD, and color, respectively at optimum pH 10.3, dosage at 162.2 mg L−1 | [28] |
| Coagulation | Neem leaves powder | pH,TS,TDS,TSS, EC, Turbidity, Alkanity Hardness, chloride, sulphate, MLVSS, Iron,silica, COD, BOD, Copper, chromium | Experimental results indicated that the wastewater could be effectively treated by using a coagulation/flocculation process, where the BOD3/COD ratio of the effluent was improved. | [29] |
| Coagulation | banana stem extract | TSS, Turbidity and hardness | Banana stem extract reduce suspended solids decreased at a percentage of 96%The hardness of 66%The turbidity decreased to 78% | [30] |
| Coagulation | MoringaOleifera and TamarindusIndica | PH, Turbidity, TS, TDS and TSS |  MO coagulant removing content 35% pH, 48% Turbidity, 68% TS, 70% TDS, 57% TSS and TamarindusIndica coagulant removing content 32% pH, 32% Turbidity, 47% TS, 48% TDS, 44% TSS. | [31] |
| coagulation/flocculation | AbelmoschusEsculentus(okra mucilage) | COD, Turbidity and color.  | A high removal of color 93.57%, turbidity 97.24%, COD 85.69% was obtained using a low amount of the okra mucilage, 3.20 mg L−1, 88.0 mg L−1. | [32] |
| Coagulation | Banana pith juice | TSS, pH, and turbidity |  Removal of EC, TS, and turbidity by using the banana stem juice were observed at pH 4 as 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 Physico –Chemical methods such as Active carbon adsorption, ion exchange, and reverse osmosis are used but all the method has disadvantages over the advantages [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 be used as natural coagulant for treatment of tannery wastewater in a concentration of 0.05g/ml,0.10g/ml,0.15g/ml and 0.20g/ml 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 were collected from local market and road side, dried at 600C for 24 hrs . The dried materials was ground in a grinder and sieved which pass through 600µm,maximum reduction in turbidity were found to be 81.20%, 82.02% and 78.54%, and maximum reduction in COD were found to be 90%, 83.33% and 75%, respectively [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, these powder used as natural coagulant and the percentage of removal of turbidity, COD, BOD, TSS and TDS were 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 aloevera is crushed at mixer in ball mill for 6 hrs at 180 rpm. The structure and morphology of aloevera coagulant were studied through Scanning Electron Microscope (SEM) and proved that it act 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 natural coagulant for the treatment of wastewater for the removal of 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 seeds gave the highest reduction of turbidity and COD at 15mg/L with pH 6 among the three, Cactus has optimal dosage at 40mg/l with pH 7. Similarly, aloevera has the optimal dosage at 5% concentration and optimal pH as 5 [40].

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Material used** | **Parameter** | **Remark** | **Reference** |
| Coagulation and flocculation | Moringaolifera, Strychnos potatorumSappindusemarginatus | 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 | Transmittance was increased to 76%. Color and odor were removed completely. Other initial parameters were also reduced drastically | [35] |
| Coagulation and flocculation | Cicer arietinum, Moringa oleifera, and Cactus | pH,Turbidity,COD | Among the natural coagulants used in this study maximum turbidity reduction of 82.02% and COD reduction of 90% was found with Moringa oleifera and Cicer aretinum, respectively. | [36] |
| coagulation and flocculation | Azadirachta indica leaves powder | turbidity, TSS, TDS, COD and BOD | Azadirachta indica leaves powder was used as coagulant and added the dosage of 3mg/L found that percentage of removal of turbidity, COD, BOD, TSS and TDS were 85.66%, 80.42%, 96.74%, 84.81% and 87.06%. | [37] |
| coagulation and flocculation | aloevera leaf | Turbidity, hardness, chlorides, TSS, Total solids, TDS, BOD and COD. | The structure and morphology of aloevera coagulant were studied through scanning electron microscope (SEM) shows amorphous nature and comparatively porous matrix which allows 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 seeds gave the highest removal of turbidity and COD for the given samples The optimal dosage of M. Oleifera is 15mg/l with optimal pH at 6. Cactus has optimal dosage 40mg/l and pH of 7 respectively. Similarly, aloe Vera has the optimal dosage at 5% concentration at optimal pH as 5. | [40] |

**Conclusion**

The removal of contaminates from various industrial wastewaters is challenging due to the presence of high strength concentration of Turbidity, TDS, TSS, COD,BOD and other complex compound. Several studies reported that the application of using natural coagulant for the treatment of wastewater gives best efficiency at low cost, less sludge production and easily available. This review studied many paper on treatment of industrial wastewater 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.

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