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RECENT APPLICATIONS OF COAGULATION, FLOCCULATION AND BALLAST FLOCCULATION IN TREATMENT OF WASTEWATER—A REVIEW

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ABSTRACT
Coagulation-flocculation is a chemical water treatment technique basically used before to sedimentation and filtration this enhances the ability of a treatment process to remove particles. Coagulation and flocculation provide the water treatment process by virtue of which finely divided, suspended and colloidal matter in the water is made to agglomerate and form flocs. This enables their removal by sedimentation, dissolved air flotation or filtration. Ballasted flocculation is a high-rate, physical-chemical clarification process, using rapid mixing flocculation and sedimentation for enhanced reduction of suspended solids and biochemical oxygen demand (BOD).
The aim of this work was to review studies, on the wide and versatile range of feasible applications employed in the purification of different types of wastewater. The coagulation-flocculation applications discussed here were for different categories: leachate, textile wastewater; pulp and paper industry wastewater; food industry wastewater; other types of industrial wastewater. In addition, this paper presents an overview of the optimum process conditions and removal efficiencies (mostly high) achieved for the technology applications discussed.

KEYWORDS: coagulation; flocculation ballast flocculation, textile, leachate, food industry, pulp and paper, Wastewater

INTRODUCTION
A very important step in water and wastewater treatment is coagulation flocculation process, which is used on large scale, because of its simplicity and cost-effectiveness., the coagulation-flocculation is usually included, either as pre-treatment or as post-treatment step regardless of the nature of the treated sample and the overall applied treatment scheme. The efficiency of coagulation-flocculation strongly affects the overall treatment performance; hence, the increase of the efficiency of coagulation stage seems to be a key factor for the improvement of the overall treatment efficiency. [6]
The purpose of coagulation and flocculation is to condition impurities, especially non-settleable solids and colour, for removal from the water being treated. Coagulating chemical is the reason nonsettleable particles clump together to form a floc. In the process of coagulation, chemicals are added which will initially cause the colloidal particles to become destabilized and clump together. The particles gather together to form larger particles in the flocculation process (see Figure1). When pieces of floc clump together, they may form larger, heavier flocs which settle out and are removed as sludge. In other cases flocs are removed from the water by flotation. (Water treatment manual, EPA)
Ballasted flocculation in conjunction with chemical coagulation rapidly enhances solid–liquid separation. Ballasted flocculation can remove more than 85% of total suspended solids (TSS), 65% BOD, 80%–90% of phosphorus, and 25%–35% of nitrogen on average. It is able to achieve good solids removal at a very high surface overflow rate. Ballast material such as micro sand, a micro carrier, or chemically enhanced sludge is effective in reducing coagulation-sedimentation time when coupled with chemical addition.
Practical review papers on Coagulation- Flocculation applications have been largely absent so far. To the best of our knowledge, only a few authors have addressed the subject re- cently, therefore, there is a need for

an update on recent applications of Coagulation Flocculation. The aim of this work was to accomplish this, and based on the literature, to present an overview of practical optimum treatment times, current densities, electricity consumption, and operating costs in a wide and versatile range of feasible applications of coagulation Flocculation in water and waste- water treatment, studied mainly during the recent years.

LITERATURE REVIEW

FOOD PROCESSING INDUSTRY WASTEWATER

Vanerkar et al. carried out the treatment of Food Processing Industry Wastewater by a Coagulation/ Flocculation Process.

They collected and characterized food processing effluent composite samples. The samples were analysed according to the procedures given in standard methods. The experiments were carried out using jar test apparatus. Six beakers of 1 litre capacity were used in which one litre neutralized effluent was taken for detail studies. Coagulant stock solutions were prepared and used for the complete set of each test. A study on the effectiveness of lime alum, ferric chloride and ferrous sulphate individually and also with addition of polyelectrolyte were carried out. Lime being the most cost effective chemical was tried first with food processing wastewater. As the wastewater pH was around 4.2 the pH was adjusted to 7.0 before the start of the experiments. A lime dose of 2.2 mg/L was required to neutralize the combined wastewater from initial pH of 4.2. The neutralized wastewater was further subjected to chemical treatment (second stage) using different conventional coagulants.

Results indicated that this wastewater is amenable to physicochemical treatment and can be applied either as pretreatment technology or as a final polishing treatment. Lime dose of 200mg/ L resulted in optimum COD/ BOD reductions of 53.59% and 57.19% respectively. Amount of sludge development was only 25 ml/L at this dose. Alum dosage resulted in very poor removals. This wastewater being highly protinous in nature alum combines with protein and forms dense fine flocs which do not settle easily. At the alum doses between 50 and 300mg/ L COD and BOD reductions varied between 16.81-29.97% and 22.81-38.81% respectively. While removals incase of Ferrous Sulphate and Ferric chloride were slightly better between the dosages of 50-175mg/L. But considering the cost of these two chemicals, lime was selected for further studies using different polyelectrolytes. Lime dose of 200mg/ L was found to be optimum. This optimum dose of Lime was kept constant and different anionic, cationic and nonionic polyelectrolytes were tried. Results showed that Magnafloc E-207 was best among the selected polyelectrolytes. Results showed 0.3mg/L of Magnafloc E-207 in combination with 200mg/L of optimum dose of Lime were very effective with COD, BOD and SS reductions of 67.61%, 71.01% and 81.53% respectively. While other two polyelectrolytes depicted more or less similar results and reduction were comparatively lesser. Both nonionic (i.e. Zetag 7650) and Cationic (i.e. Oxyfloc FL-11) showed 0.4 mg/L of polyelectrolyte as optimum.

TEXTILE INDUSTRY WASTEWATER

Junior et al. performed Study on coagulation and flocculation for treating effluents of textile industry. They investigated the optimization of time of coagulation, flocculation, and sedimentation of the chemical coagulant, aluminum sulfate and natural coagulant, Tannin. The main characteristics of the effluent generated by the stamping industry were: neutral pH, significant amount of total solids and metals, high COD and BOD5, dark color and high turbidity. It was performed an economic analysis of the process, checked the removal efficiency of color, turbidity, COD, and treatment characterization using metals, BOD5, and total solids.

The tests were conducted in Jar Test, using different mixing and sedimentation times. The time required to provide the rapid and slow mixing were 2 and 20 minutes, respectively, for the investigated coagulants, with optimum concentration of 400 mg L-1 for Tannin and 600 mg L-1 for Aluminum Sulfate. For the analyzed parameters, the percentage of removal, according to the best optimization test were 93.12, 99.06 and 99.29% for COD, color, and turbidity, respectively, using the coagulant aluminum sulfate, and 94.81, 99.17 and 99.65% for COD, color and turbidity, respectively, using the coagulant Tannin. The natural and chemical coagulants presented a very effective removal of color.

The treatment using the natural coagulant, tannin, removed the largest amount of organic matter (expressed in COD) for the characterization of the effluent considering BOD5, total solids, and metals, there was a decrease in these parameters with both coagulants, but tannin had the best results

LEACHATE WASTEWATER TREATMENT

Rui and daud studied the Efficiency of the coagulation-flocculation for the Leachate treatment coagulation-flocculation examined the effectiveness of alum and ferric chloride as well as the use of cationic polymer and micro zeolite on removal of suspended solid (SS), color, COD and ammoniacal nitrogen (NH3N) from leachate.

Experiments were first carried out without prior adjustment of pH (8.3) using different coagulant dosages (0.2, 0.3, 0.4, 0.5 and 0.6 g Fe^{3+}/L). The reductions in COD were very low, ranging between 9.5 % and 11%. However, using a dosage ≥0.5 g/L, the reduction in turbidity reached values of 6.9 for a dosage of 0.6 g Fe^{3+}/L and 7.4 for a dosage of 0.2 g Fe^{3+}/L. experiments were subsequently conducted at different pH employing the same dosage of ferric chloride, 0.5Fe^{3+}/L, with the aim of determining the optimum pH. The optimum pH was found to be 3.8, obtaining reductions in COD, color and turbidity of 26%, 84%, and 90%, respectively. The next goal was to determine the optimum reagent dosage. Dosages ranging between 0.3 and 0.7 g Fe^{3+}/L were tested, obtaining an optimum value of 0.4 mg/L with reduction in COD, color and turbidity of 28%, 78% and 90% respectively.

Experiments were once more conducted without prior pH adjustment for different dosages of aluminium sulphate (0.3, 0.4, 0.5 and 0.6 g Al^{3+}/L). It was found that the greater the dosage of aluminium sulphate employed, the higher the turbidity removal. Turbidity removal was similar for dosages of 0.5 and 0.6 g Al^{3+}/L (around 80.7%). The effluent pH ranged between values of 7 for a dosage of 0.3 g Al^{3+}/L and 6.4 for dosage of 0.6 g Al^{3+}/L. the dosage of 0.5 g Al^{3+}/L was employed to determine the optimum pH range, which is situated around 6, obtaining very high reduction in turbidity (92%) and color (77%), though not in COD (20%). The optimum dosage of aluminium sulphate was then determined for this optimum pH value. This was found to be 0.8g Al^{3+}/L, with removal percentages of COD, color and turbidity of 27%, 84%, and 93% respectively. Landfill leachate composition varies widely among landfills. This variation makes a through characterization of leachate mandatory for each landfill before appropriate treatment schemes can be defined.

PAPER AND PULP INDUSTRY WASTEWATER

Pradeep Kumar et al. carried out treatment of Paper and Pulp mill effluent by coagulation. Integrated pulp and paper mill generates wastewater with very high BOD and COD, toxic substances, recalcitrant organics, pH, turbidity, high temperature and intense color.

The batch coagulation process was performed using various coagulants like: aluminium chloride, poly aluminium chloride and copper sulphate. The initial pH of the effluent (Coagulation pH) has tremendous effect on COD and colour removal. Poly aluminium chloride (PAC) as coagulant reduced COD to 84 % and 92 % of colour was removed at an optimum pH 5 and coagulant dose of 8 ml l^{-1}. With aluminium chloride at an optimum pH = 4 and coagulant dose of 5 g l^{-1}, 74 % COD and 86 % colour removal were observed. The results using copper sulphate as coagulant (a less commercial coagulant) were encouraging. At an optimum pH 6 and mass loading of 5 g l^{-1}, 76 % COD reduction and 78 % colour reduction were obtained. It was also observed that after addition of coagulant, the pH of the effluent decreases. The decrease in pH was highest for $AlCl_3$, which was followed by PAC and $CuSO_4$. Significant amount of COD reductions was obtained by coagulation process. The copper has been found to be good oxidation catalyst then iron and aluminum

FLUORIDE-CONTAINING WASTEWATER

Wang et al. performed a Pilot-scale fluoride-containing wastewater treatment by the ballasted flocculation process. A pilot-scale ballasted flocculation system was used to remove fluoride from one type of industrial wastewater. The system included the formation of calcium fluoride (CaF_2) using calcium hydroxide followed by coagulation sedimentation. Calcium fluoride was recycled as nuclei for enhancing

CaF2precipitation and as a ballasting agent for improving fluoride removal and flocculation efficiency. Factors affecting fluoride and turbidity removal efficiencies, including pH in the CaF2-reacting tank and coagulation-mixing tank, sludge recycling ratio, and dosages of FeCl3 and polyacrylamide (PAM), were investigated in the pilot-scale system. The recycled CaF2precipitates improved CaF2 formation kinetics, enhanced fluoride removal and flocculation performance. Under the optimized condition, the ballast flocculation process reduced fluoride concentration from 288.9 to 10.67 mg/L and the turbidity from 129.6 NTU to below 2.5 NTU.

WATER, WASTEWATER AND CSO TREATMENT

Kumar et al., studied ballasted sand flocculation for water, wastewater and CSO treatment Different types of coagulants, flocculants and micro-sand of varying dosages, depend on influent hydraulic loadings and their water-quality constituents' characteristics, are used in BSF. The coagulant dosages of alum and ferric chloride normally vary from 8 to 40 mg/l and 40 to 190 mg/l, respectively; the flocculent dosages (cationic/anionic polymer) vary from 0.3 to1 mg/l and the micro-sand (size 40–150 μm) dosages from 2 to 12 g/l based on type and characteristic of water/wastewater. In most of the cases, the removal rate of turbidity, TSS and T-P were reported above 90% and BOD above 60%. The removal rate of other parameters (viz. coliforms, COD and trace elements) was also reported satisfactory.

BSF system has been found a promising technology for clarification of drinking water and in reducing pollution load of wastewater and CSO treatment system before its pathways to biological processes, or natural water systems.

LITERATURE REVIEW CLOSURE

A summary of recent applications of coagulation flocculation with different types of water and wastewater has been discussed in this research work. Such as,
Food Processing Industry Wastewater Treatment,
Textile Industry Wastewater Treatment,
Leachate Wastewater Treatment,
Paper and Pulp Industry Wastewater Treatment
Fluoride-Containing Wastewater Treatment
CSO Treatment etc

Various parameters like Removal efficiencies, economic values and essential operational parameters in optimum process conditions are presented along with other specifications. Along with this paper discusses the behavior of coagulant and its combination with various polyelectrolytes, BSF technology and its effect on its processes, chemical and sand dosages, performance, usefulness and drawbacks.

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