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A Review of Water-Soluble Polymer Flocculant as an Alternative to the Traditional Uses of Alum

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Abstract

The ability of organic polymer-rich coagulants for water treatment was studied. An improved method for the removal of the active coagulant agent from the seeds was employed. The effects of four variables including pH, coagulant dosage, dye concentration, and time were analyzed. Response surface methodology (RSM) using face-centered central composite design (FCCD) was used to optimize the four variables. Increases in the colour removal efficiency were higher in acidic solutions. Accurate control of coagulant dosages gave optimum destabilization of charged particles and re-stabilization occurred at above 800mg/L. Polymer performances were measured through a time-dependent decrease in particle concentrations following aggregates growth. The verification experiment agreed with the predicted values having less than 4% standard error. An overlay contour plot was used to establish an optimum condition for the multiple responses studied. The response surface method was suitable for improving the flocculation-coagulation process while minimizing the number of experiments. Coagulants studied should be considered as an alternative to conventional coagulants that are widely used in water treatment

1. Introduction

The scarcity of water and water-related diseases has inspired scientists to keep working on natural coagulating agents such as banana peel, *Moringa oleifera* seed extract, and several other natural coagulants that might be used as a water-soluble polymer flocculant as an alternative to the traditional uses of alum [1]. Flocculation is a method whereby small particles in suspension are caused by either addition of chemical substances or natural substances to aggregate, giving large flocs (clusters) that are much more easily parted than the original particles. Flocculant is also a long-chain water-soluble polymer used to separate fine solids particles from aqueous suspensions. According to [2], there is no unanimously recognized formal definition for flocculation, but it is mostly accepted that flocculation is the accumulation of solids attained with the help of high molecular weight polymers through the development of bonds between particles It is also a vital component used in mineral processing, municipal and industrial wastewater treatment, paper making oil sand tailing dewatering and biotechnology. Whereas, Coagulation is a communal method used for eradicating suspended matter from water. This method is used in many industrial applications. Destabilization of colloids by physical phenomenon is induced by several chemical agents such as ferric chloride, poly alum salts [3]. Some chemical products such as polyacrylamides are added to water in order to accelerate the coagulation processes by increasing the floc size due to the slow process of the ferric chloride, polyalum salts, and this process is referred to as flocculation [3].

According to [4]. *Moringa olifera* is a humid tree that comes from sub-Himalayan basins. It is a multi-purpose tree whose properties have been known since a long time ago and several authors have referred to several aspects of significance. Animal nutrition [5] and human pharmacology [6] cosmetics, etc. Several researchers have their different explanations of the utilization of *Moringa oleifera* for water treatment. According to [7], the seeds of tropical trees are a special pollutant removal, and the seeds have a high quantity of proteins that act like cationic polyelectrolytes once they are added to raw water as reported by [8]. However, characterizing the flocculant process in drinking water is a very vital task due to this fact. *Moringa oleifera* has been pointed out by institutions such as the Food and Agricultural Organization of the United Nations (FAO) in this aspect of the interest [9].

Water-soluble polymer flocculants as an alternative to traditional uses of alum are significant constituents of solid-liquid separation units for the treatment of a variety of process-affected effluents [10]. The systematic development of a flocculant relies on a good understanding of the flocculation process, polymer synthesis, polymer characterization, and, not the least, flocculation performance assessment as desired for a particular treatment process, all of which are essential to establish meaningful relationships between flocculant microstructure and flocculation efficiency [11]. The objective of this review was to evaluate the use of water-soluble polymer as an alternative to the traditional use of alum for water treatment or purification. The recent improvement in the application of synthetic, bio/natural, and stimuli-responsive flocculants are reviewed. Then, the basic polymer reaction engineering tools to regulate the microstructure of flocculants that have been provided and the techniques for the quantification of flocculant microstructure. This is followed by a review of the methods adopted by different authors for the characterization of particle-polymer flocculation/ dewatering assessment and force measurement, and with consideration to the characterization of combined structures [12;16].

This review evaluates the use of water-soluble polymer as an alternative to the traditional use of alum for water treatment or purification. And this will be determined through the review of various literature to determine the cost effect of Water-soluble polymer flocculants on solid-liquid separation units for the treatment of a variety of process-affected effluents and the availability of the water-soluble flocculant in developing countries like Nigeria. Also, to determine the environmental benefit of water-soluble coagulants to know if they are technically feasible for small-scale business utilization.

2.0. Concept of flocculant

Flocculation and coagulation are important processes in numerous disciplines [17]. clarification of water using coagulating agents for potable water treatment has been practiced from the olden. The Egyptians used almonds smeared around vessels to clarify river water as early as 2000 BC [18]. The use of alum as a coagulant by the Romans was mentioned in around 77 AD [19]. According to [20], who carried out a study on the Treatment of effluents of construction industry using a combined filtration-electrocoagulation method revealed that Alum was being used for coagulation in municipal water treatment in England in 1757. Also, Shalley [21] conducted research on Collection of Field Data for Stormwater Model Calibration and the result of the study unveiled that Water treatment in modern development, flocculation, and coagulation are still important mechanisms of the general suite of treatment processes – this is justifiable because today the regulatory limit in the

US for treated water turbidity has progressively reduced from 1.0 NTU in 1989 to 0.3 NTU since 1989. To guard against pathogen contamination, many water utilities are committed to constantly producing treated water turbidities of less than 0.1 NTU. Whereas, Natural polymers have long been used as flocculants. For instance, according to Sanskrit literature from around 2000 BC references the use of crushed nuts from the Nirmali tree (Strychnos potatorum) for clarifying water – the practice is active till today in parts of Tamil Nadu, where the plant is known as Therran and cultivated also for its medicinal properties [22]. Generally, the value of natural polymers is that they are virtually free of toxins, biodegradable in the environment and the raw products are often locally available. Therefore, the use of synthetic polymers is more prevalent. In general, they are more active as flocculants due to the level of control made likely during manufacture [23].

2.1. Flocculant Characterization

According to [5], The detailed characterization of the microstructure of commodity polymers, such as polyolefins, is a well-studied subject, which has permitted enormous advances in this area over the last decades. Unfortunately, the research community working on the development of polymer flocculants often fails to properly quantify the microstructure of their polymers, which would otherwise permit them to establish quantitative microstructure-performance relationships for their flocculants. The often-reported properties of flocculants are typical molecular weights, fundamental viscosities, and normal chemical structures. While depicting these properties offers some tools to improve the structure of a polymer flocculant, the absence of full polymer microstructure quantification such as chemical composition distribution (CCD) and molecular weight distribution (MWD) does not provide the essential intuition into the relationships between flocculation/dewatering performance and their flocculant microstructure. According to (14), who carried out a study on Structure and sedimentation characterization of sheared $Mg(OH)_2$ suspensions flocculated with anionic polymers unveiled that there are some techniques that can be used to quantify the microstructure of flocculants such as Measurement Performances of Flocculant–Particle Interaction which laid emphasis on Interfacial services between polymers and particles, which result from the surface energies of polymer and particles chains, which eventually control the flocculation process. Frequently, the flocculation performance of a polymer reflects interactions of polymer molecules and suspended. Furthermore, these interactions strongly influence the rheological properties of the sediments, which are vital in numerous applications such as dewatering. In this section, we briefly introduce and review the recent state of the art focused on the use of quartz crystal microbalance with dissipation (QCMD), atomic force microscopy (AFM), and surface force apparatus (SFA), which are considered powerful techniques to quantify flocculant–particle interactions.

2.2. Advantages of flocculants

Flocculants are inorganic salt such as $FeCl_3$ or Al $(SO4)_3$, as well as synthetic organic polymer [6]. While these compounds are relatively active in eradicating suspended matters and dyes from the aqueous solution, several shortcomings have arisen recently, such as their influence on human diseases like neurotoxin and Alzheimer's caused by inorganic salts [1], and carcinogenic effects [2] caused by poly acryl amides or acrylic amide. Hence, these problems can be solved by considering the use of natural coagulants extracted from plants. Natural polymer coagulants are of the emerging trend by many researchers because of their abundant source, low price, environmental friendliness, multifunctionality; they do not alter treated water pH and biodegradability in water. In this study, the active coagulant was extracted from the seeds of cowpea (Vigna unguiculata), fluted pumpkin (Telfairia occidentalis), black timber (Brachystegia eurycoma), Bambara nut (Vigna subterranean), and horse radish (Moringa oleifera) were used for decolorization of Azocarmine G dye. The seeds extract is characterized to be a soluble cationic protein and possesses the ability to act as a natural polymer coagulant [6; 7, 8].

According to [12], the natural ingredient of an organic polymer is important as it encompasses acrylamide monomers that are less expensive as compared to conventional chemicals and harmless to human health, and available since they are available in most rural communities. Therefore, the bid for this natural product as part of point-of-use in water treatment technology may offer a cheap, practical, appropriate, and sustainable resolution for potable water production in some developing countries. A study conducted by [25], stated that the recent advancement in the coagulation field, concerning the development of the coagulation chemicals, is under investigation. The study went further to reveal that the development of simple polyaluminium chloride (i.e., pre-polymerized coagulants) seems no longer to be adequate, Therefore, there is a need for more active coagulants which has led to the development of new coagulant categories, through the introduction of several additives in the building of pre-polymerized coagulants. The study further stated that the first effort was reported 15 years ago, suggesting the use of silica in the form of polysilicates for such a drive. Currently, the choice of additives has extended, with the use of organic compounds, such as cationic, non-ionic polyelectrolytes, or anionic leading to new compound coagulants. Generally, it is obvious that the propensity in the coagulation field currently is the manufacturing of improved compound coagulants, which are becoming more and more difficult, regarding their composition, nevertheless more effective, when compared with the traditionally use chemicals (alum).

3.0. Reported work in Nigeria on the use of water-soluble polymer flocculant as an alternative to the traditional use of alum.

A study carried out by [12] on review of Moringa Oleifera Seed as Alternative Natural Coagulant for Potential Application in Water Treatment revealed that originally, there is evidence to recommend that plant-based materials are still used by communities in the developing countries as one of the approaches for purifying drinking water. In this analysis, Moringa oleifera seeds extracted were the coagulant properties that were quantitatively assessed toward appropriate wastewater treatment and investigating its coagulation mechanism. The study unveiled that the seeds of Moringa Oleifera are used as a natural coagulant for effective water treatment and are also rich in bio-active components. The study further stated that the seeds extract operates mostly by operates through charge neutralization and bridging coagulation mechanism. Research conducted by [15], revealed that the efficiency of locally obtainable okra pod powder as a natural coagulant under varying settling times, dosage, and pH in the removal of turbidity from dye wastewater at room temperature has been assessed. The researcher employed the use of the application of single angle Turbidimeter measurement for the experiment and kinetic and functional parameters such as coagulation period ($\tau_{1/2}$), and coagulation rate constant (K), were determined. Statistical parameters such as a sum of squares due to error (SSE), coefficient of determination (R^2), and the root mean square error (RMSE), were also used to assess the adequacy of the process. The result unveiled the highest value of 1.7×10^{-4}L/mg.min for K was recorded at pH 4 and 100 mg/L dosage with $\tau_{1/2}$ of 14.91 min and the least value of K, 3.6×10^{-5}L/mg.min was recorded at pH 8 and 300 mg/L doses with $\tau_{1/2}$ of 70.43 min respectively. The result further revealed that the efficiency of turbidity removal of more than 80% and 95% was attained at the end of 3 mins and 30 mins settling time respectively, signifying a system controlled by the perikinetic method of coag-flocculation. The results showed the potential of pulverized okra pod for the removal of suspended particles from dye effluent.

4.0. Water-soluble polymer flocculant and its prospects to Nigeria

Effluents produced from chemical industries are characterized by the presence of chemical contaminants and turbidity of heavy metallic ions [9]. Exposure to lead (Pb), for instance, is known as a key threat that influences human and animal diseases, and the building of industrial ecological schemes have also made exposure to lead (Pb) inevitable for most people alive today [13]. In the field of water pollution, the removal of pollutants and noxious metals from industrial wastewater is a subject of great interest, which is a solemn cause of water degradation [16]. Flocculation-Coagulation is a technique generally used for effluent treatment particularly if the effluent is discharged into surface water [9]. flocculation/Coagulation is also a process usually used in wastewater and water treatment through which a compound such as ferric polymer or chloride is added to an effluent discharge in order to weaken the colloidal materials and cause the small particles to agglomerate into bigger settleable flocs [7]. Hence, the futuristic use, as well as the present disadvantages of this process, is essential for the treatment of effluents discharge in developing countries Nigeria [15]. According to [10], Industrial effluent is one of the major problems currently facing Nigeria and numerous efforts are being strongly followed to resist it in various manufacturing industrial spanning the length and breadth of the country to see that Nigerians live in an environment free of diseases. The effluent produced by the industries is the major source of pollution. Air Contamination, water, and soil contamination by effluents generated from the industries are accompanied by heavy disease burden [10] which could be part of the reasons for the present shorter life span in Nigeria [11] when compared to the developed nations. Hence, with the use of our natural resources to treat the effluents generated from the various manufacturing industries in the country, it will go a long way to save lives and increase the life expectancy of every Nigerian. A study carried out by [18] on the characterization of textile industries' effluents in Kaduna, Nigeria, and pollution implications unveiled that air quality of the area covered by the entire Kaduna River basin could be negatively affected by both the gaseous emissions and particulates which could be released from the industrial effluent. the result also clearly stated that the qualities of effluents in the study areas were completely below the standard set by the Federal Ministry of Environment in Nigeria and some world bodies like the World Health Organization in four of the five textile mills which could be the reason for the high cost of the traditional use of alum. Therefore, water-soluble flocculant can be considered for the treatment of the industrial discharge of effluent at a very low cost [21;26]. The review of water-soluble polymer flocculant as an alternative to the traditional use of alum will also open the eyes of many Nigerians to the importance of the natural resources they have and how they can be harnessed in solving different problems like scarcity of potable water through an easy and economical way of treatment or recycling of the wastewater and also to prevent the discharge of raw wastewater into the environment by small or large industries in Nigeria which in turns pose threat to the environment and contamination of other water bodies as a result of lack of treatment before discharged [17]. The study will also open the eyes of Nigeria on how to boost their economy with the use of the various resources they have instead of focusing on one resource to boost their economic boost by reducing the use of purchased chemicals used in water treatment and lay more emphasis on this water-soluble polymer flocculant method that is cost-effective [14].

5.0 Conclusion

The demand for good water resources for protecting the environment and future generations from pollutants has motivated researchers to produce efficient polymer flocculants that could increase the performance of dewatering units with minimum cost. Our review indicated that there has been a large body of literature in recent years concentrating on introducing new polymer materials as water-soluble flocculants for a variety of applications including mineral processing, wastewater treatment, and oil sands tailings treatment. More attention has been growing on the In-depth performance characterization of flocculants for the treatment of targeted effluents to further optimize their performance.

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