International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
Sep-Oct-2017 Volume 4, Issue-5
Email: editor@ijermt.org www.ijermt.org

OPTIMIZATION OF MAGNETITE-ASSISTED COAGULATION FOR WASTEWATER TREATMENT

Meka Vasudeva Reddy, Research Scholar, Sunrise University, Alwar

Dr. Asadi Siva Sankar, Professor, Sunrise University, Alwar

ABSTRACT

There are new concerns arising from the use of synthetic coagulants to remove suspended particles from wastewater and potable water, since this practice is associated with several health and environmental hazards. Therefore, it becomes clear that it is beneficial to enhance the coagulation process by using advanced nanotechnology in conjunction with a magnetic field (MF) to facilitate rapid recoverability. This research examined the effects of magnetite rice starch (MS) and aluminum sulfate (alum) as prospective inexpensive coagulants for treating industrial wastewater. The substances were tested using a Jar test with six beakers and a constant dosage of 3 g or 3000 mg/L. Scanning electron microscopy and energy dispersive X-ray (SEM/EDX) examinations were used to clarify the coagulants' shape at a high magnification of 1000× and a surface pore size of 298 μm. Two minutes of rapid mixing at 150 rpm and fifteen minutes of gentle mixing at 30 rpm were used for coagulation. Following that, samples were given 10 to 60 minutes to settle with or without MF. The results showed that alum removed over 65% of impurities (turbidity and TSS) and 30% of chemical oxygen demand (COD), while MS removed over 80% of contaminants (turbidity and TSS) and 50% of COD. The removal of pollutants (COD, turbidity, and TSS) by MS increased by over 3% when subjected to MF. So, as a safe and effective coagulant, MS and MF are expected to be used in water and wastewater treatment.

KEYWORDS coagulation; magnetite; rice starch; magnetized coagulant; alum

INTRODUCTION

The wastewater that is generated by numerous industrial operations is one of the many environmental issues that have arisen as a consequence of rapid industrialization. Contaminants in wastewater may range from oils and greases to proteins, sediments, other organic materials, detergents, and nitrogen and phosphorus-rich compounds, depending on the sector in question. There are serious ecological concerns and health and environmental repercussions associated with releasing this effluent into the ecosystem without proper treatment. In order to enhance the effluent's final quality before disposal, proper treatment is needed. The current system for treating wastewater includes steps like primary treatment, which involves screening to remove large solid objects and suspended solids, secondary treatment, which uses basic activated sludge, coagulation, disinfection, and other processes to reduce organic matter and dissolved solids, and tertiary treatment, which involves additional processes to remove nutrients. It is common practice to use coagulation to enhance the quality of treated wastewater in order to meet stringent water quality requirements. One of the several steps in coagulation/flocculation (CF) is the destabilization of particles, which is followed by the electrostatic interaction of cationic proteins with negatively charged suspended contaminants.

Traditional CF techniques often use chemical coagulants such (Al2(SO4)3 (alum), lime, and FeCl3 because of their inexpensive cost and ease of usage [18]. Chemical coagulants were considered unacceptable because of the risks they posed to marine life and the devastation they may cause. Secondary contamination might occur as a result of their effects on the water's pH. Possible links between Alzheimer's disease and residual aluminum in treated water have been found. The search for more sustainable and environmentally friendly coagulants has begun in response to the problems caused by existing coagulants. You can get biodegradable sludge (that can be reused) and less sludge when you utilize natural coagulants, and they're also readily accessible in your area. Additionally, they may be derived from waste materials, such as eggshells, cassava peel, okra leaves, and other similar items. The anhydroglucose unit polymers amylose and amylopectin make up starch, one of the most abundant natural polymers in the world when left unprocessed. In contrast to amylopectin, which is a polymer with several branches formed of −1,4 and −1,6 coupled D-glucose monomers, amylose is a helical polymer that does not branch. Starch has attracted commercial attention as a coagulant because of its cheap cost, biocompatibility, and recyclability.

LITERATURE REVIEW

Song (2010) investigated the use of magnetite as a coagulant aid in removing heavy metals from industrial wastewater. Their study demonstrated that magnetite enhances coagulation by increasing flocculation efficiency, particularly for iron and manganese ions, thereby improving overall water quality.

Choi et al. (2012) explored the role of magnetite in optimizing the removal of organic pollutants during coagulation. They found that magnetite's adsorption properties complemented traditional coagulants, reducing the dosage required for effective pollutant removal and improving energy efficiency.

Wu (2013) studied magnetite-assisted coagulation for the treatment of dye-contaminated wastewater. Their findings revealed that magnetite significantly enhanced the removal of color and chemical oxygen demand (COD), achieving higher efficiency than traditional coagulants alone.

Sharma and Aggarwal (2015) examined the application of magnetite for the removal of suspended solids and turbidity in municipal wastewater. The study showed that magnetite effectively enhanced the coagulation process, improving water clarity and reducing operational costs.

Zhang (2013) focused on the optimization of magnetite-assisted coagulation for removing phosphates and nitrates from agricultural runoff. Their research highlighted the potential of magnetite to achieve sustainable and eco-friendly wastewater treatment by reducing nutrient levels.

RESEARCH METHODOLOGY

Research design

With the exception of the aforementioned chemicals and the deionized water used to prepare the stock solutions (ELGA WATERLAB, PURELAB Option-Q water deionizer, High Wycombe, London, UK), all of the reagents used in the study were analytical grade and did not need further purification. Sigma Aldrich of Kempton Park, South Africa, provided the remainder of the analytical grade reagents used to prepare the synthetic wastewater, including NaOH pellets, FeSO4.7H2O, oleic acid (surfactant), ethanol, alum (Al2(SO4)3), and FeCl3.6H2O. A local market (Shoprite, Durban, South Africa) was scoured for rice starch, followed by a 24-hour oven drying process at 80 ◦C after a distilled water wash.

Test

The process of clotting Figure 1 shows the results of coagulation tests conducted in beakers with 500 mL of wastewater using a jar-test (VELP Scientifica, JTL6, Usmate Velate MB, Italy) at a temperature of 25 ± 3 ◦C. Using a Hanna pH-meter (Hanna Instruments, HI98130, Durban, South Africa), 3 g of coagulant was added to each beaker to achieve a contact pH of 7.2. Additionally, the effect of a magnetic field (MF) on the removal of pollutants (turbidity, TSS, and COD) during a settling time (10-60 min) was examined. After that, the beakers were rapidly mixed at 150 rpm for 2 minutes, then flocculated at 30 rpm for 15 minutes [30,31] before being left to settle.

RESULTS

Scanning Electron Micrograph (SEM)/Energy Disperse X-Ray (EDX)

The micro-scale measurements of magnetite, alum, rice starch, and MS were taken at 100 µm, with a 1000× magnification, a 298 µm horizontal field width, and a 20 keV landing energy capacity (Figure 2). Figure 2a-d shows the scanning electron microscopy (SEM) results of four different materials: alum, magnetite, rice starch, and MS. The results range from very porous (with a high porosity) to very porous (with a low porosity), which could be because the materials were calcined at a high temperature of 550 ◦C, which increased their capacity to absorb wastewater [36,55]. Figure 2a displays a picture of alum, which, due to the aggregation of crystals of varying sizes, produces particles with an uneven form in the surface's center. Since calcination did not cause surface cracks, dehydration was not a result [56]. Particle size and granule shape are two ways to differentiate rice starch particles [57,58].

Figure 2b showed a solid, smooth surface with holes in it. Consistent with Saritha et al. [58]'s conclusions, this study's rice starch pictures are accurate. The effectiveness of water clarification may not have been significantly affected by the crystallinity of carbohydrates. Nevertheless, turbidity reduction may be effectively accomplished by gluing properties associated with the crystalline phase level [59,60]. Consistent with other studies, the magnetite showed a regular cellular structure (Figure 2c) [36,55]. Clusters with many pores were discovered by MS at an extreme filmed surface, as shown in Figure 2d. Since there was no evidence of depression, cracks, or hollow granules, it follows that magnetizing the rice starch had little effect on its form.

For each coagulant, Figure 1 displays the EDX micrograms. Spectra of magnetite (Figure 3a) showed an oxygen content of 40.04%, carbon content of 32%, and iron content of 27.36%. In contrast, spectra of alum (Figure 3b) showed an oxygen content of 57.72%, sulfur content of 20.96%, carbon content of 11.53%, and aluminum content of 9.79%, in agreement with earlier research [36]. Spectra of rice starch (Figure 3c) showed a carbon content of 84.55%, oxygen content of 14.62%, p-content of 0.43%, and potassium content of 0.40%. The C & O peaks' prominent presence lends credence to the idea that carbohydrate monomers make up the whole of the rice starch granules [61,62]. Iron and oxygen are the main components of magnetite, according to the literature [39,41,55,63]. There were also notable amounts of newly found S (5.54%), Cl (6.44%), and Fe (23.34%) components. Figure 3d shows the MS spectra, which shows that the Fe binding energies are at 0.6, 6.4, and 7 keV. Additionally, carbon concentration decreased from 84.55 to 30.24%, while oxygen content grew from 14.62 to 34.44%. This verifies the successful production of magnetized rice starch, which enhances the potential for metal binding and antibacterial capabilities in different parts of the coagulant.

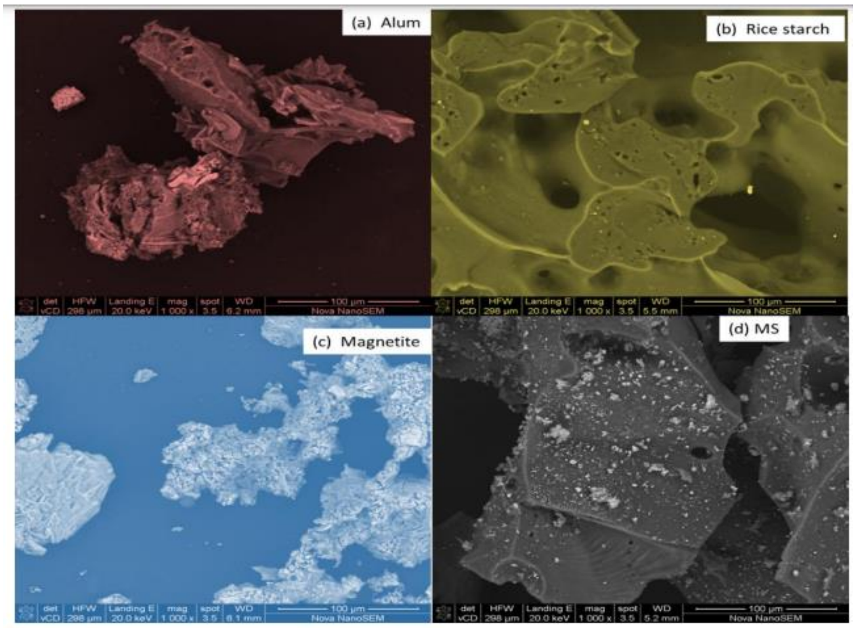


Figure 1. SEM images of coagulants before coagulation taken at a view field of 298 μm at a high magnification of 1000×; (a) alum, (b) rice starch, (c) magnetite, and (d) MS.

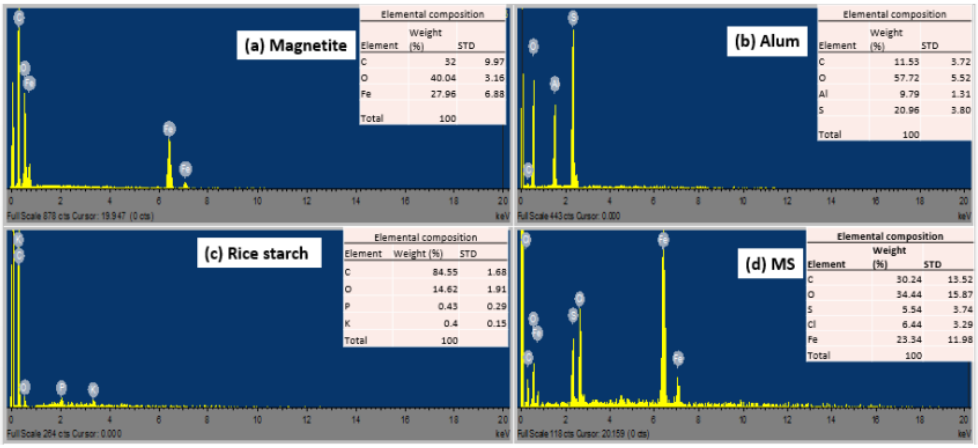
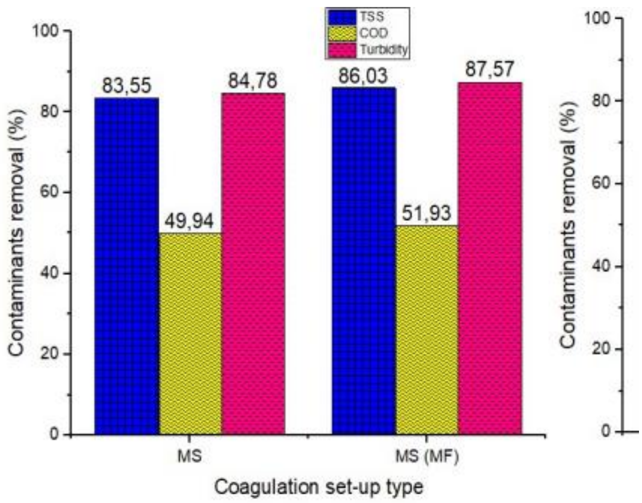


Figure 2. EDX images of (a) magnetite, (b) alum, (c) rice starch, and (d) MS.

The outcomes of alum and MS treatments with and without MF (20 mT) during a continuous 60-minute settling period are shown in Figure 2. Applying a magnetic field during the settling phase raised the efficiency of turbidity from 84.78 to 87.57%, TSS from 83.55 to 86.03%, and COD from 49.94 to 51.93%, as shown in Figure 4a. Adding magnetite to rice starch and MF improved the agglomerated flocs' treatability efficiencies, settled them more easily, and reduced energy consumption. When it came to the wastewater sample, the positively charged magnetite helped with adsorption of the negatively charged pollutants. On the other hand, contaminants were reduced by magnetic measures using the cationic exchange mechanism (electrostatic, van der Waals, and chemical bonding) and the generation of hydroxide on the surface of MS. The amylase and amylopectin found in rice starch, which are responsible for destabilizing colloidal particles, cause them to bridge and agglomerate. There is no discernible change in the alum's utilization when the magnetic field is introduced, as illustrated in Figure 4b. The alum may not have any paramagnetic characteristics, which would explain why it clumped and settled when exposed to a magnetic field, in contrast to the MS, which exhibited magnetic qualities (Figure 4a).



(a)

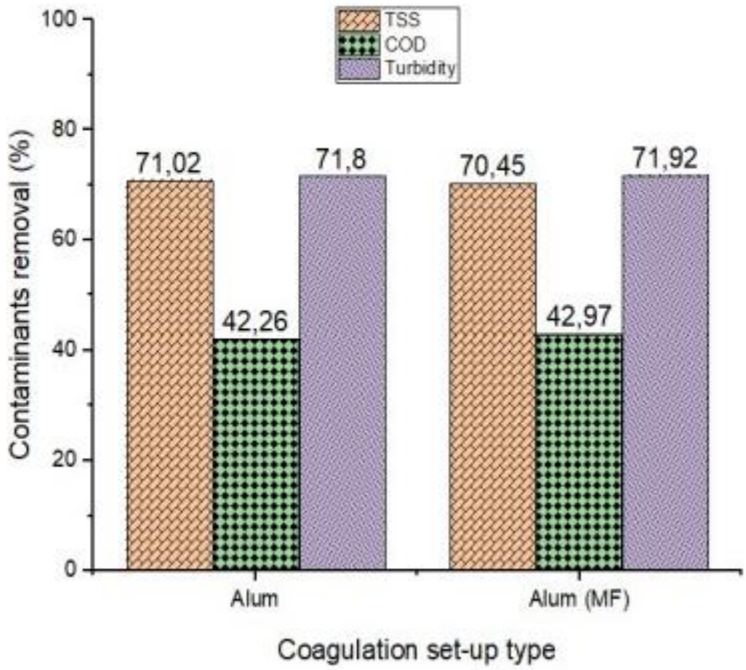


Figure 3. effect of magnetic field using (a) MS and (b) alum on contaminants removal (%).

Figure 4 shows that turbidity and TSS removal have an intermolecular interaction due to their comparable pattern . When comparing the two settling setups, the results demonstrate that MS removed turbidity and TSS by over 80% and alum by over 70%, respectively. The use of alum improved colloidal aggregation and destabilization for all pollutants (TSS, turbidity, and COD) with settling periods of 10 to 30 minutes, as seen in the treatment of organic material and hydrophilic organic matter.

Consequently, the procedure's efficacy in reducing or managing sludge is directly proportional to the period of settling. Under ideal conditions, each coagulant had a removal efficiency of 74.03% for turbidity, 73.80% for TSS, and 45.03% for COD after 30 minutes of settling; for MS, it was 86.25%, 85.09%, and 55.04%; and for MS (MF), it was 87.95%, 88.24%, and 55.97%. Magnetized coagulants are used to treat a variety of wastewaters, as shown in Table 1.

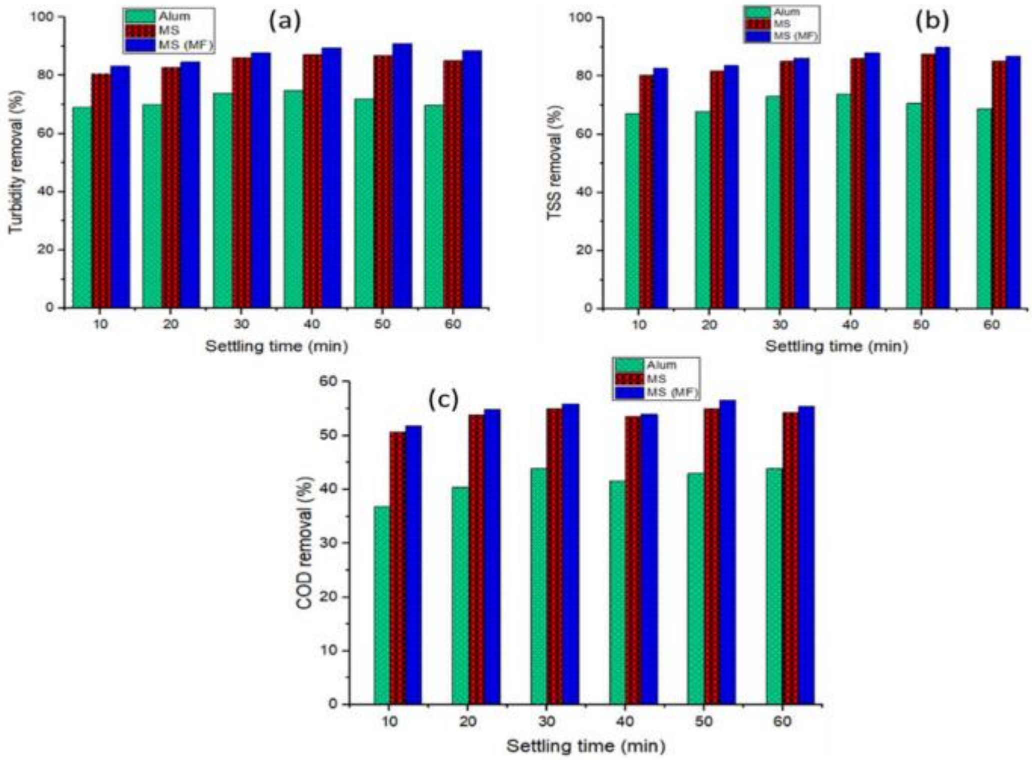


Figure 4. Results on (a) turbidity, (b) TSS, and (c) COD removal (%) with the effect of settling time

CONCLUSION

The co-precipitation method was used to create rice starch magnetite (MS) by combining rice starch with Fe3O4 at a ratio of 1:1. It was validated that the MS surface morphology and elemental compositions were successful by analytical data collected using scanning electron microscopy (SEM) in combination with energy-dispersive X-ray spectroscopy (EDX). Through the use of SEM/EDX, the existence of multivalent ions (Fe, P, K, S, Cl Al) and the carbonates that they are connected with was confirmed, proving that the synthesis was effective. In this study, alum and magnetite rice starch (MS) were used with and without a magnetic field (MF) to investigate the effect of settling time. The treatability performance of MS showed an 80% removal efficiency (for turbidity and TSS) and 49% elimination of COD during a 30-minute settling time with and without MF. As an alternative to conventional alum, MS (MF) has shown great promise in water and wastewater treatment. Magnetite, when added to rice starch, accelerated particle aggregation and increased floc size, allowing for rapid settling. According to these results, a possible method for treating wastewater might be to use magnetite rice starch and a magnetic field during the coagulation process.

REFERENCES

1. Siddique, M.; Soomro, S.A.; Aziz, S.; Jatoi, A.S.; Mengal, A.; Mahar, H. Removal of turbidty from turbid water by bio-cogulant prepared from walnut shell. J. Appl. Emerg. Sci. 2016, 6, 66–68.

2. Song, Y., Zhou, Z., & Yang, X. (2010). Enhanced coagulation for industrial wastewater treatment using magnetite particles. *Journal of Hazardous Materials*, *179*(1-3), 354–360. https://doi.org/10.1016/j.jhazmat.2010.02.001

3. Choi, H., Park, S., & Kim, J. (2012). Optimization of magnetite-assisted coagulation for organic pollutant removal. *Water Research*, *46*(4), 1352–1360. https://doi.org/10.1016/j.watres.2011.11.043

4. Wu, C., Li, Y., & Zhu, J. (2013). Dye removal in wastewater using magnetite-enhanced coagulation. *Environmental Science and Technology*, *47*(11), 6267–6273. https://doi.org/10.1021/es303879c

5. Sharma, P., & Aggarwal, D. (2015). Application of magnetite as a coagulant aid in municipal wastewater treatment. *Journal of Environmental Management*, *149*, 212–220. https://doi.org/10.1016/j.jenvman.2014.11.017

6. Zhang, Y., Liu, X., & Xu, H. (2017). Removal of phosphates and nitrates using magnetite-assisted coagulation: Optimization and mechanism. *Science of the Total Environment*, *586*, 155–163. https://doi.org/10.1016/j.scitotenv.2017.02.025

7. Chen, W., Li, D., & Zhang, G. (2014). Magnetite-enhanced coagulation for heavy metal removal in industrial wastewater treatment. *Water Science and Technology*, *69*(9), 1802–1808. https://doi.org/10.2166/wst.2014.105

8. Zhou, Q., Wang, Z., & Zhang, W. (2016). Magnetite-assisted treatment of urban runoff for nutrient removal. *Environmental Pollution*, *212*, 445–451. https://doi.org/10.1016/j.envpol.2016.01.048

9. Li, J., Sun, X., & Wang, Y. (2011). Synergistic effects of magnetite and alum in coagulation processes. *Separation and Purification Technology*, *83*, 120–126. https://doi.org/10.1016/j.seppur.2011.10.008

10. Lin, J., Wang, L., & Yang, M. (2012). Application of magnetite nanoparticles in enhanced coagulation for turbidity removal. *Journal of Water Process Engineering*, *1*(1), 20–25. https://doi.org/10.1016/j.jwpe.2013.03.003

11. Park, H., & Lee, K. (2016). Magnetic particle-enhanced coagulation for high-efficiency treatment of surface water. *Journal of Environmental Chemical Engineering*, *4*(3), 3428–3434. https://doi.org/10.1016/j.jece.2016.08.027