THE CANADIAN SCIENCE FAIR JOURNAL

ARTICLE

Coagulant Conundrum: Comparing the Efficacy of Natural and Chemical Coagulants on Microplastics

By: Katharine Morley | Edited by: Sabina Yasmin | Layout by: Sarah Derikx

Age: 15 | Victoria, BC

Bronze Excellence Award (CWSF) | Nanotechnology for Sustainable Society Award (CWSF) |Fifth Overall (Vancouver Island Regional Science Fair)

Microplastics (MPs) are tiny plastic particles less than 5 mm in size that are a growing concern to our environment. Scientists have found them practically everywhere - in honey, beer, and most prominently, in our oceans (Diaz et al., 2020). These contaminants take almost a century to degrade and may have carcinogenic properties. As I live by the ocean, I am very passionate about protecting our waters and keeping them clean. I was compelled to find out how we can remove these pesky, persistent particles from water.
One strategy for this is coagulation, a method of water treatment that reduces colour and turbidity of water. How it works is that the positive charges of a coagulant neutralize the negative charges of suspended particles in a colloid. This process forms larger particles, which can then be more easily extracted with a filter. Types of coagulants include chemical coagulants (e.g., aluminum sulfate, polyaluminum chloride, and ferric chloride) and natural coagulants (e.g., *Moringa oleifera* (*M. oleifera*), *Cactus latifolia*, and *Strychnos potatorum*). An incredibly scarce amount of work has been done on the effectiveness of natural coagulants, and even less so on coagulating MPs, which is why I chose to dive deeper into this topic.

INTRODUCTION

The main goal of this project is to determine whether natural or chemical coagulants are more effective at coagulating MPs. Being economical and environmentally friendly, natural coagulants have benefits over chemical ones and could be pursued as a key means of coagulation if they prove to be as effective. The results of my experiments could be used to further the development of coagulation for the removal of MPs and to find a way to apply it in a real-world situation such as performing it on larger bodies of water. I tested two different coagulants: *M. oleifera*, a mineral-rich plant native to India used in some countries as a lower-cost water treatment solution, and aluminum sulfate, used in coagulation for water treatment as well as in paper manufacturing and dyeing fabric.

I conducted a few experiments to compare the effect of two coagulants on MPs, investigate their efficiency further in different pH environments and finally test the two coagulants on MPs together in synergism. I predicted that the coagulant *M. oleifera* would be more effective at coagulating MPs because of its high positive charge structure due to a natural cationic protein that it contains, as well as its high charge density (a large number of positive charges in a substance gives it a stronger ability to neutralize charges).

METHODS AND MATERIALS

The main materials used included: *M. oleifera* seeds, aluminum sulfate powder, MP samples, a pipette, water, a petri dish, and mason jars. To concoct the natural coagulant, oil was extracted from around 500 *M. oleifera seeds*. First, the seeds were cracked open with a rolling pin, and shells were manually removed. Next, the seeds were roasted to brown the exteriors. Once cooled, they were ground to a fine powder. 250 ml of water was added to dissolve the powder. The mixture was then sifted through a cheesecloth, with the remaining solid left for use in the experiment.

MPs were created by vigorously shredding a solid piece of plastic with a lemon zester until the desired amount of MP samples was reached (around 32 ml in total). A baseline suspension was created by filling a glass jar with 100 ml of tap water and adding 2 ml of a MP sample. After shaking the jar for 90 seconds it was left for 30 minutes to settle. Samples were collected using a pipette: five individual samples of 1 ml were extracted from the suspension and examined in a Petri dish with a magnifying glass. The data was collected by manually counting and averaging the number of MPs in each sample. The process was similar for the rest of the experiment where coagulants were added to MP suspensions - three jars contained *M. oleifera* extract and three jars contained aluminum sulfate, with different quantities of the respective coagulant (1 ml, 2 ml, and 3 ml). The shaking and settling process was the same to allow particles to coagulate at the suspension's surface. Five individual 1 ml samples were again taken from the top of the suspension where most coagulation occurred and were examined in a petri dish with a magnifying glass. The number of MPs in each sample was counted and averaged.

I also tested the coagulants on water with different pH levels. To do this, the pH level of water in 6 jars was altered using HCl (to increase acidity) and NaOH (to increase basicity). 3 ml of each coagulant was tested on pH levels 6, 7, 8, and 9. This range was selected in regards to each coagulant's optimum pH range of coagulation. All other preparations and data collection procedures remained the same.

A third experiment was done with the two coagulants combined (1.5 ml of each, 3 ml in total) using the concept of synergism. A median pH level of 7.5 was chosen for the test, but all other procedures were consistent with previous experiments.

RESULTS AND DISCUSSION

For the first experiment (different dosages of coagulant) aluminum sulfate proved to be most effective at coagulating MPs. The average number of coagulated MPs of aluminum sulfate was almost twice the amount of *M. oleifera*, and just about 10 times more than no coagulant at all. *M. oleifera* still showed promising results, just not to the same degree as aluminum sulfate. I accumulated some interesting results with the average number of MPs coagulated per quantity of coagulant. For aluminum sulfate, the effectiveness increased as the dosage rate increased. At 3 ml it produced the highest result, coagulating on average 104 MPs. The samples were so large that there were virtually no more MPs left to draw a fourth sample from that suspension. For *M. oleifera*, the effectiveness stayed constant throughout all three quantities of coagulant - only coagulating more MPs than aluminum sulfate at one of three dosage rates (1 ml). See Appendix A (table 1).

The increase of efficacy with aluminum sulfate as the dosage rate increased likely demonstrated that aluminum sulfate becomes more effective as greater amounts are used - up to a certain extent (Sun et al., 2019). It is possible that the consistency in results of *M. oleifera* throughout dosages could be due to its low dosage capability (Imron et al., 2020) - 1 ml of *M. oleifera* was almost as effective as 2 ml of *M. oleifera*, but with just half the quantity. Overall, the performance of the two coagulants could be explained by the pH level of tap water used. The average tap water pH of Greater Victoria is 6.99 (CRD, 2018). The suggested level of pH for optimum performance by *M. oleifera* is 7-9 (Desta, Bote, 2021), and approximately 6.5-7.2 for aluminum sulfate (Brandt, Ratnayaka, 2017), though some sources suggest a general range of 6-7 pH. The tap water that I used had a pH level that aligned closer to aluminum sulfate's optimum range, which may indicate why it proved to be more effective than *M. oleifera* at the coagulation of MPs.

The results of the study on the different pH (see Appendix A, table 2) provided fascinating results. Both coagulants had a stronger performance in their respective projected optimum fields. It is notable that *M. oleifera* exceeded the relative success that aluminum sulfate had in its optimum pH range. Aluminum sulfate showed the best results at a pH level of 7, coagulating on average 36 more MPs per sample than *M. oleifera*, which coagulated 76 more MPs on average in its prime pH of 8 than its chemical counterpart. This data could also help account for the results of experiment 1 (Appendix A, table 1), and why aluminum sulfate was most effective. It also opens up a new opportunity; while aluminum sulfate is best for coagulating MPs in tap water pH, *M. oleifera* could be a considerable option for coagulating MPs in ocean water, which has an average pH level of 8.1 (USEPA, 2021).

In my third experiment when coagulants were combined, effectiveness was neither greatly improved nor diminished. On average 98 MPs were collected - close to the average amount of MPs *M. oleifera* and aluminum sulfate collected when averaged between 7 and 8 pH (109 and 89 respectively). No notable difference resulted.

CONCLUSION

Both aluminum sulfate and *M. oleifera* proved to be effective coagulants in their own right. Aluminum sulfate performed best at a 3 ml dosage at a pH of 7, while *M. oleifera* performed best at a dosage of 3 ml at a pH of 8 (but showed consistency through lower dosages). With the pH level in mind, aluminum sulfate could be considered for further development for coagulation of MPs in distilled water while *M. oleifera* could be pursued as a potential option to treat MPs in the ocean. However, more research is required to confirm these ideas. The ongoing experiment on other types of MPs may help determine the consistency of these results.

ACKNOWLEDGMENTS

I am extremely grateful to those involved in my project and would like to thank the following people: my mom (support), Mr. Basaraba (guidance), Ms. Dallin (advising), and Mr. Osbourne (lab advice/materials).

REFERENCES

Brandt, M. J., & Ratnayaka, D. D. (2017). *Aluminum Sulphate.* Science Direct. Retrieved November 10, 2021, from https://www.sciencedirect.com/topics/engineering/aluminium-sulphate

CRD. (2018, April). *Greater Victoria Drinking Water Quality*. Greater Victoria Drinking Water Quality. Retrieved March 14, 2022, from https://www.crd.bc.ca/docs/default-source/crd-document-library/plans-reports/drinking-water/2017-greater-victoria-drinking-water-quality-annual-report.pdf?sfvrsn=9914f6ca_2

Desta, W. M., & Bote, M. E. (2021, November). *Greater Victoria Drinking Water Quality*. Greater Victoria Drinking Water Quality. Retrieved March 14, 2022, from https://www.crd.bc.ca/docs/default-source/crd-document-library/plans-reports/drinking-water/2017-greater-victoria-drinking-water-quality-annual-report.pdf?sfvrsn=9914f6ca_2

Diaz, M. F., Conesa, J. A., & Fullana, A. (2020, July 8). *Microplastics in Honey, Beer, Milk and Refreshments in Ecuador as Emerging Contaminants.* MDPI. Retrieved March 9, 2022, from https://www.mdpi.com/2071-1050/12/14/5514/htm

Imron, M. F., Kunayawan, S. B., Abdullah, S. S., Said, N. M., Ismail, N. I., Hasan, H. A., Othman, A. R., & Purwanti, I. F. (2020, December 12). *Challenges and Opportunities of Biocoagulant/Bioflocculant Application for Drinking Water and Wastewater Treatment and Its Potential for Sludge Recovery*. NCBI. Retrieved March 9, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7764310/

Sun, Y., Zhou, S., Chiang, P.-C., & Shah, K. J. (2019, June). E*valuation and optimization of enhanced coagulation process: Water and energy nexus*. Science Direct. Retrieved March 14, 2022, from https://www.sciencedirect.com/science/article/pii/S2588912520300011

USEPA. (2021, September 30). *Understanding the Science of Ocean and Coastal Acidification | US EPA*. US Environmental Protection Agency. Retrieved March 14, 2022, from https://www.epa.gov/ocean-acidification/understanding-science-ocean-and-coastal-acidification

APPENDIX A

Table 1: Experimental data for Different Dosages of Coagulant

Coagulant	Quantity of Coagulant (mL)	Average Number of Microplastics per Sample
Moringa Oleifera	1	33
	2	37
	3	38
Aluminum Sulfate	1	28
	2	70
	3	104
Baseline (No Coagulant)	n/a	5

Table 2: Experimental data on Different pH Levels

pH Level	Average Number of Microplastics per Sample	
	Moringa Oleifera	Aluminum Sulfate
6	75	84
7	74	110
8	141	65
9	115	51

ABOUT THE AUTHOR - KATHARINE MORLEY

Katharine Morley is a grade 10 student at Glenlyon Norfolk School in Victoria, BC. She is interested in various areas of science but is particularly passionate about environmental science. With this project, Katharine competed for the first time at the CWSF. Outside of academics she is committed to a serious dance program (ballet, contemporary, and Irish dance) and has trained in two summer intensives at Canada's National Ballet School.