The Effectiveness of Bio-Organic Polymers in the Purification of Wastewater by Removal of Microplastics via Coagulation and Flocculation

Background

Microplastics, which are non-degradable and unsafe to humans and other organisms, have contaminated almost all water supplies used. With sizes of less than 5 millimeters, microplastics are undetected in water purification processes, but they can be removed using coagulation/flocculation. Colloidal microplastics do not settle out from water because their size causes ionic surface charges to have intermolecular attractions with polar water molecules that stabilize the mixture. If hydrophilic coagulants are added, these compounds, adopting a positively-charged structure in water, can neutralize the microplastics, which adopt a negatively-charged structure. The resulting microplastic-coagulant complex cannot interact with polar water molecules favorably, destabilizing the colloid and causing the microplastics to settle in flocs, with the potential to be filtered and removed from the water. There exist naturally occurring polymers that have inherent cationic properties, making them candidates for coagulants. The three coagulants used here are *Strychnos potatorum* (Nirmali) seeds, *Pandalus borealis* (Caridean shrimp) shells, and *Manihot esculenta* (Cassava) peels.

Hypothesis

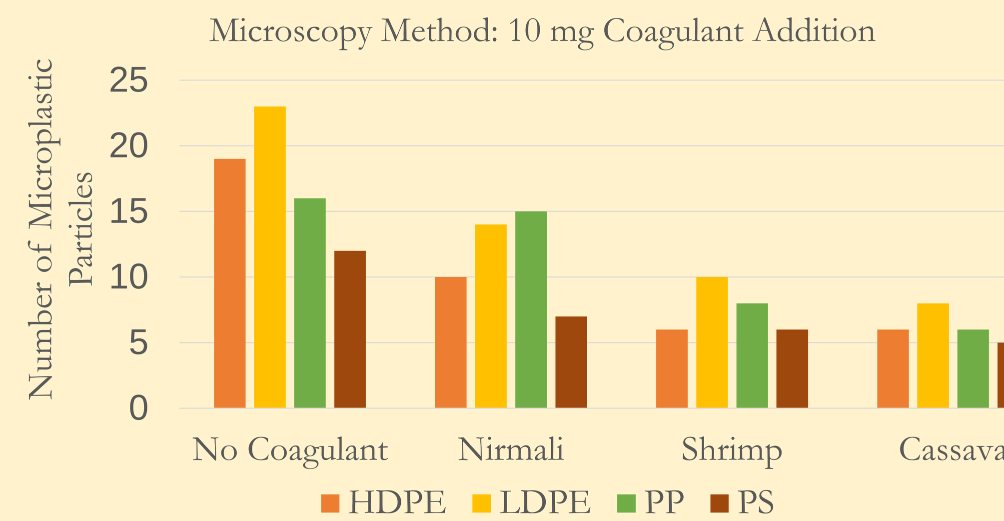
This project was designed to determine an optimal method of removing dissolved microplastics from contaminated water using biologically-originating coagulants, as opposed to organic and inorganic coagulants. The project determines a method to make water treatment for microplastics safer, more efficient, and environmentally friendly. It was hypothesized that *Strychnos potatorum* seeds would act as the best coagulant for the removal of microplastics and for trapping this debris, because of how efficiently they work in water purification processes used in rural activities in my native country.

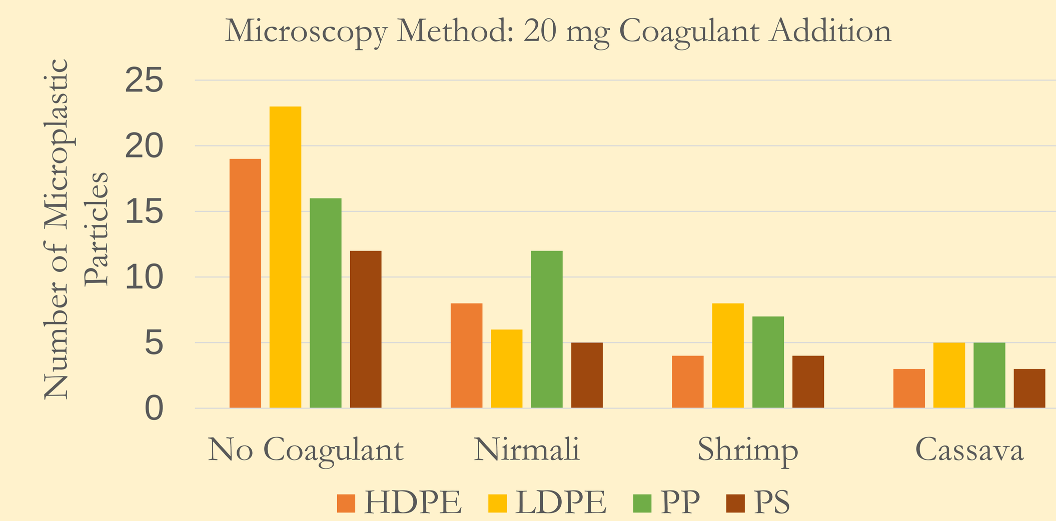
Methods and Procedures

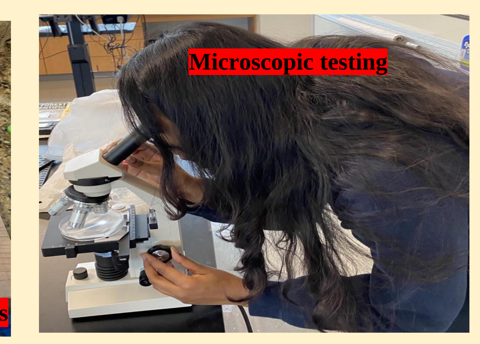
Abundant samples of HDPE, LDPE, PP, and PS were obtained from a tough water bottle, a frozen-food bag, a yogurt container, and a plastic cup, respectively, using a metal rasp, ground into fine powders, and passed through a 5 mm metal mesh sieve to collect final samples. 10 mg of each sample was added to individual 50 mL beakers filled with distilled water and a pre-pipetted drop of dishwashing soap liquid to reduce the surface tension of the water and allow the mixture to form. This was performed individually for each of the 3 experimental coagulants. The solutions were mixed using a magnetic stirrer for 10 min, followed by measurement of samples' turbidity using 3 methods. Abundant samples of *Strychnos potatorum* seeds, dried *Manihot esculenta* peels, and dried *Pandalus borealis* shells were separately ground using a blender and passed through the sieve. 10 mg, for the first trial, and 20 mg, for the second trial, of each sample was mixed with individual 50 mL beakers filled with distilled water using a magnetic stirrer for 5 min. After 30 min, the mixture was passed through a double-layered filter, with the residue added to its respective set of microplastic/water beakers, mixed using a magnetic stirrer for 15 min, settled for 30 min, and filtered using a triple-layered filter. The filtrates were collected and turbidities were measured using the 3 methods.

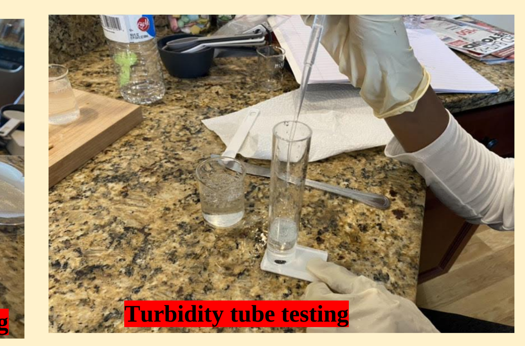
Results

Method 1, Microscopy: 2 mL of each solution was pipetted and passed through a double-layered filter, with the residue collected, transferred onto Petri dishes, dried, and transferred to under a light microscope. The number of microplastics presented in each sample was counted. A hot needle was used to test if particles were indeed plastic, as contact with the needle causes plastic melting.

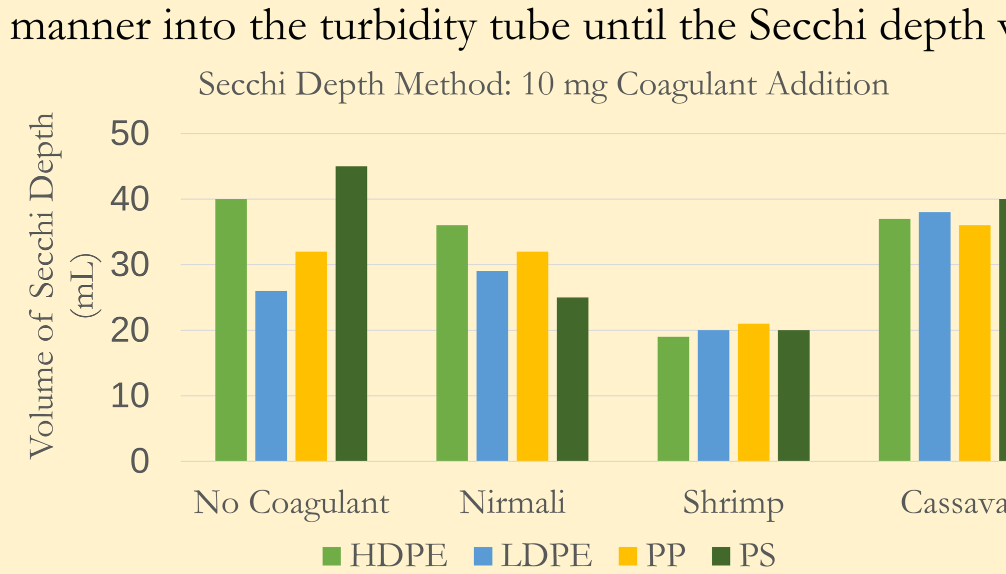


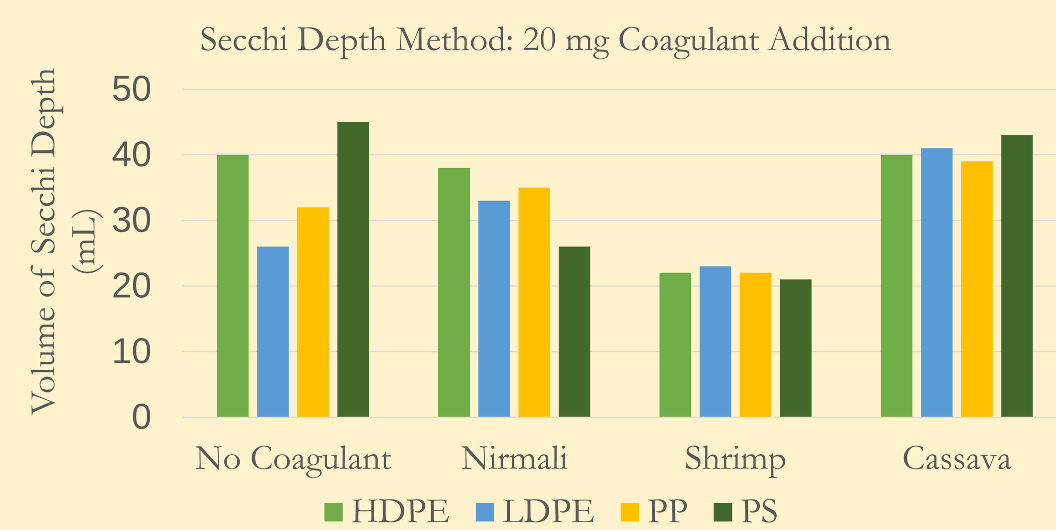


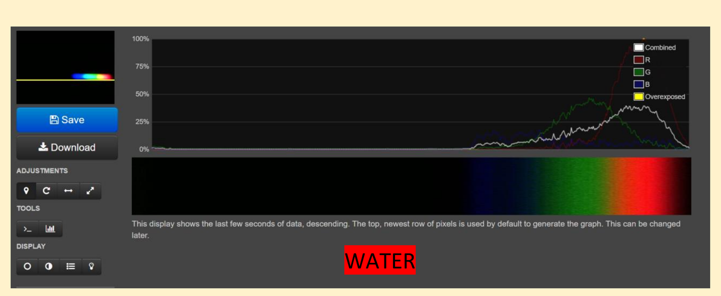




Method 2, Turbidity Tube: A 3/4-inch-diameter 50-mL transparent plastic turbidity tube, with gradations, was used. The measurement of the Secchi depth of contaminated water samples using a Secchi disk consisting of a circle divided into four equal sectors oppositely shaded black and white, such that the Secchi depth is equal to the water sample's depth at which point any apparent visibility of distinguishing the disk from the water is eliminated, was used. Each filtrate sample was pipetted in a controlled manner into the turbidity tube until the Secchi depth was reached.

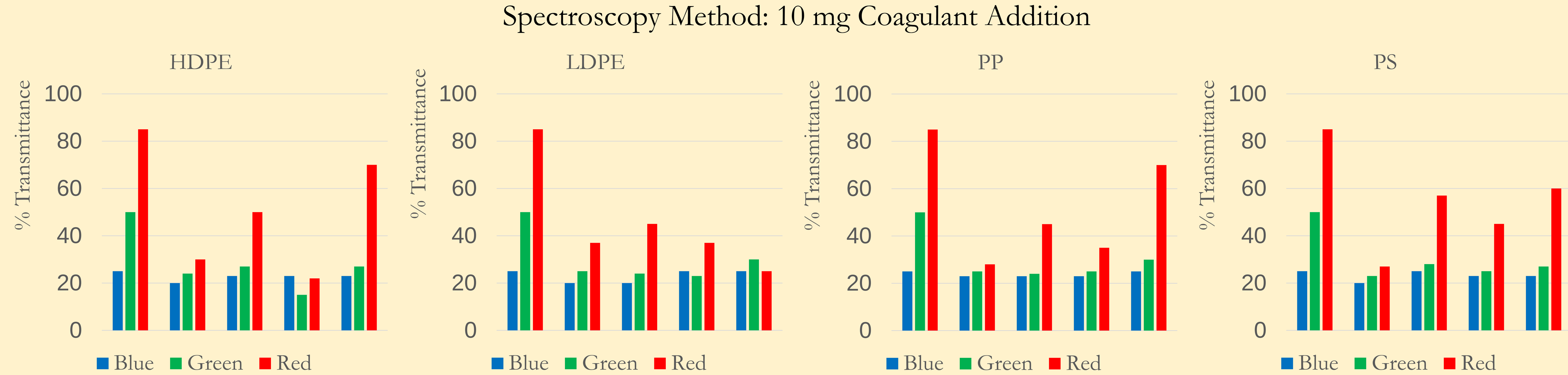






Method 3, Spectroscopy: A spectrometer was built from a cardboard box lined with black paper on the inside and with a small slit cut to allow light's passage. A USB-equipped webcam was installed inside the box at a 45 degree to the direction of light rays. A standard CD piece, with the silver lining peeled off and the reflective plastic material retained, was used to produce a diffraction grating on top of the camera lens. A lamp was placed outside of the box, ahead of the slit by 12 inches. Beakers were placed between the slit and the light source 6 inches from each. Spectrometer readings were recorded using the SpectralWorkbench.

Spectroscopy Method: 10 mg Coagulant Addition



Columns are as follows: Water / Microplastics (MP) / MP + Nirmali / MP + Shrimp / MP + Cassava

Discussion

Manihot esculenta was the most efficient coagulant, most likely due to an abundance of amino acids in these samples relative to the others, since research has revealed that amino acids have significant capabilities in removing pollutants. With regards to *Strychnos potatorum* and *Pandalus borealis*, there existed contradicting results. Using the Secchi Depth method, *Strychnos potatorum* was superior, but using the microscopy method, *Pandalus borealis* was superior. This may be due to invalidity in the Secchi Depth test, caused by using raw *Pandalus borealis* shells instead of specifically chitosan, an efficient coagulant derived from shrimp. By not using purely this, excess cloudiness could have occurred by the existence of other nonessential compounds in the shells. The results demonstrate that the coagulants were more effective in treating water contaminated with plastics of lower densities. Thus, limiting humanity's usage of high density plastics can allow water purification to occur more efficiently.

The project's results were valid due to the usage of three separate testing methods to determine coagulation efficiency. The project implemented a magnetic stirrer to evenly mix samples for controlled time periods. Following solution preparation, all testing was performed within a limited time frame in controlled environments. Implementing distilled water free of chlorine improved the reliability of spectrometer readings. However, there may have existed errors in experimentation. In the spectroscopy method, one possible confounding factor may have been that different samples were exposed to different amounts/intensities of light due to external factors, causing less or more light to be able to pass through the water sample. There may also have been variations in beaker positioning, potentially altering results of spectroscopy.

In future research, it would be ideal to test new flocculants, in addition to the original coagulants, to analyze their impact on microplastic samples. Specifically, alum, which is well-known for being a very efficient flocculant, would be a possible candidate for testing. In addition, other types of microplastics, as well as their mixtures, should also be tested to determine the impact of coagulants/flocculants on water contaminated with them. Investigation should also be performed regarding combining coagulants with natural polymers, which have been used before to enhance coagulation efficiency, to supplement these biological coagulants in treating contaminated wastewater.

Conclusions

Efficient natural coagulants must be implemented in order to purify contaminated water for human and organism usage. As this project demonstrates, only certain coagulants have substantial effectiveness. *Manihot esculenta* was the best of the three investigated coagulants, with *Strychnos potatorum* and *Pandalus borealis* working moderately well. None of the coagulants worked as well as initially expected, possibly due to having limited experimentation to purely microplastic removal instead of general wastewater purification, or simply due to inefficacy on the part of the coagulants. Regardless, this project provided conclusive results on how bio-organic polymers can be used as coagulants to remove microplastics from contaminated water to a substantial degree during treatment procedures.