

Oyster Filtration Efficiency in NYC Stormwater Conditions with Addition of Mangrove-prototype & Tannins

Quality of Life INNOVATIONS Proposal

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Summary

Eastern Oysters (*crassostrea virginica*) are nature's great water filters and are commonly found in NYC. However, during storms, stormwater runoff carries many pollutants and suspended particles into waterways which pose a threat to Eastern Oyster populations. Our study aims to reduce the suspended particles (turbidity) in the waterways using oysters, mangrove-like prototype, and tannins. In our study, using the Kruskal Wallis test, we found that there is a relationship between mangrove-prototype, tannins, and oysters and turbidity levels. Additionally, the mangrove structure and tannins performed the best at improving oyster filtration efficiency and water quality in turbid stimulated stormwater conditions. Therefore, we recommend implementing a mangrove-prototype with oysters near Combined Sewage Overflow (CSO) sites where stormwater runoff and pollutants are concentrated. This can reduce risk of disease, reduce water pollution, reduce turbidity levels, and support oyster population restoration.

Background Research

Oysters are nature's water purifiers: a single reef containing them can filter thousands of gallons daily, clearing murky waters, cycling nutrients, and turning polluted waters into vibrant, thriving ecosystems. *Crassostrea virginica*, also known as the Eastern Oyster, filters out up to 50 tons of water per day. They are a vital marine keystone species, and their activity is crucial to the survival of marine inhabitants. As a result, oysters, specifically the *Crassostrea*, are one of most used marine species in aquaculture (1). However, in the last couple of decades, *Crassostrea Virginica* populations and their fisheries have suffered severe and widespread declines globally (2) due to trapping and water pollution. Above all, climate change has posed a significant implication on urban environments as temperature rises, causing more precipitation events. Some implications include: increased water acidification, rising water temperatures, high salinity, invasive species, algal blooms, and other environmental factors (2). However, the most severe implication is stormwater runoff.

Stormwater increasingly poses an issue in New York City (NYC) as stormwater runoff affects water quality. During seasons of heavy rainfall events, frequent stormwater runoff can overwhelm drainage infrastructure and waterways, causing erosion, infrastructure damage, spreading pollutants, etc. In extremely urbanized areas such as New York City, stormwater contains lots of pollutants such as sediment, heavy metals, microplastics, pesticides, and bacteria (3), which get washed into waterways during heavy rainfall events – a process called combined sewage overflow (CSO). This leads to highly polluted canals, rivers, lakes, and waterways putting global water quality at risk. Sewer overflow also poses high exposure risk to pathogens in wastewater, causing diseases such as asthma,

chronic obstructive pulmonary disease, gastrointestinal illnesses, and other diseases that stem from long term exposure to pollutants during a CSO event (4). This puts public health as a detriment to poor surveillance of sewage overflow and lack of action to resolve this issue.

An annual report recording the number of CSO events in 2024 revealed that 50% of CSO events occurred in NYC than in any other New York cities (5). NYC's main sewage system is the combined sewage system (CSS) which facilitates the collection and disposal of domestic sewage water, industrial wastewater, and stormwater runoff into publicly owned treatment works (POTW) where wastewater is treated and then discharged into public waterways. However, during heavy storm events, the mass amount of stormwater mixed with wastewater in the CSSs leads to a sewage overflow as the volume of wastewater exceeds the capacity of the treatment plant leading to untreated sewage and industrial waste water to be washed into the waterways and entering the oceans (5). Another factor is turbidity and according to a study by Sandén and Håkansson in 1996, turbidity levels in bodies of water are rising due to human activity in coastal areas (6). Turbidity is the degree of how transparency of a fluid decreases due to suspended particles, measured in Nephelometric Turbidity Unit (NTU), and the total suspended particulate matter generally inhibits the growth of oysters by diluting the organic matter at high levels (7). The sources of turbidity are linked to human activities that involve nutrient input through wastewater negligence and erosion through waterways (8). Additionally, turbidity is responsible for the decrease in light penetration needed for photosynthesis, decreasing food production and dissolved oxygen solubility levels that are harmful to oyster populations (9).

In response to these issues, policies have been enacted by the government as an attempt to alleviate the issue of stormwater runoff. These policies, however, have been proven to be ineffective as the sewage overflow rate is increasing as climate change increasingly poses risks of heavy rainfall events (1). Early policies include the Unified Stormwater Rule (USWR), mandating the development of new infrastructure to enable water retention as an attempt to reduce flooding as well as improving water quality, and permits for construction sites (SPDES, MSGP, CGP, MS4 GP). However, these only addressed some of the sources of the issue but failed to address the issue of runoff water. The Clean Water Act (CWA) as well as the Water Pollution Control Act prompted NYC to conduct an area-wide water quality assessment in the 1970s to address the CSO problem. This laid the foundation for current CSO abatement policies as CSO remains a significant issue to the quality of life, so much so that the city was compelled to implement a city-wide CSO abatement program by New York State's State Pollutant Discharge Elimination System (SPDES) in 1985 (10). Many of these policies mandate the use of a system to filter water artificially for usage. Even so, these enacted policies still failed to address the issues of the water runoff, ignoring the long term view of the current issue with increasing stormwater runoff in NYC waters and not taking into account the vitality of marine organisms. Many nonprofit organizations were established to assist in the effort to preserve marine organisms and improve quality of life simultaneously. The Billion Oyster Project (BOP) is one of the major nonprofit organizations that strive to preserve ecosystems, develop shoreline protection, and increase water filtration. BOP seeks to recover a functional and self-sustaining oyster population in the New York Harbor by implementing a multi-acre restoration project that adds oyster spat and reef substrate in four regional waterbodies that make up New York Harbor: the Hudson River, Western Long Island Sound, Upper/Lower New York Harbor, and Jamaica Bay. Their goal is to restore one billion oysters to 100 acres of land by 2035 and to address factors that

inhibit the recovery of these oyster populations (11) such as turbid waters that reduce the growth of aquatic microorganisms that oysters consume as a result of reduced sunlight intake. These studies are indicative of the dangers of CSOs and their aftermaths. As a result, more studies need to be conducted to counter the effects of CSOs on aquatic ecosystems. Even though it is well established that oysters play a key role in keeping the marine ecosystem clean, more research should be done on how oysters can be used as a solution to CSOs as it affects marine and human life.

Field Research and Analysis

This field research serves to test whether the addition of natural coagulant and a mangrove like structure would improve oyster filtration efficiency in stormwater conditions. For this experiment, we partnered with the Billion Oyster Project and had three oyster tanks set up in the school's environmental classroom.

This experiment was situated in a classroom with three 5 gallon oyster tanks. We labeled each tank 1, 2, and 3 respectively. Tank 1 was the control experiment with 21 spat, tank 2 was experimental 1 with 17 spat, and tank 3 was experimental 2 with 23 spat. Each tank had different experimental variables (Table A).

Tank	Description
Control (tank 1)	Oysters + Kaolin clay
Experimental #1 (tank 2)	Oysters + Kaolin clay + Mangrove Prototype
Experimental #2 (tank 3)	Oysters + Kaolin clay + Tannins

Table A

We used observation methods for our research. We hypothesized that oyster filtration efficiency would increase with the addition of the mangrove-like prototype and tannins. Thus, the experiment began with the design of the mangrove prototype. Mangrove roots are tightly knit which can be good at trapping suspended particles and can act as a barrier to floods. We used branches picked from a local park and arranged them in a way that resembled mangrove roots (18). The BriSunshine Lab Turbidity Meter was used to measure the turbidity of the water samples. The NYC stormwater conditions were simulated through a mixture of kaolin clay, fine sand, and tank water until 80 NTU. Kaolin clay was used as it can turn water turbid quickly and is found in sand. In tank 3, we added 10 mL of tannin extract which raised the turbidity to 95 NTU. Tannins are naturally found in leaves and act as a natural coagulant which can be beneficial in removing suspended particles.

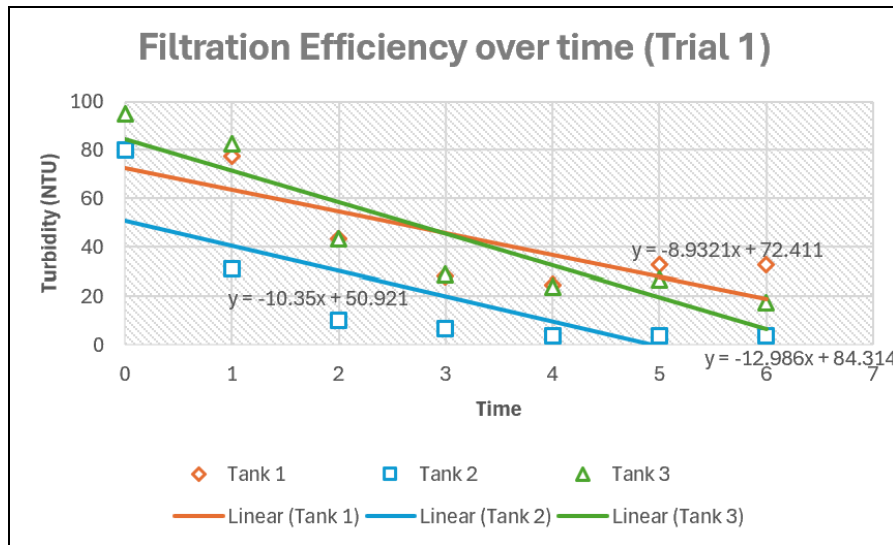
18). *Branches*



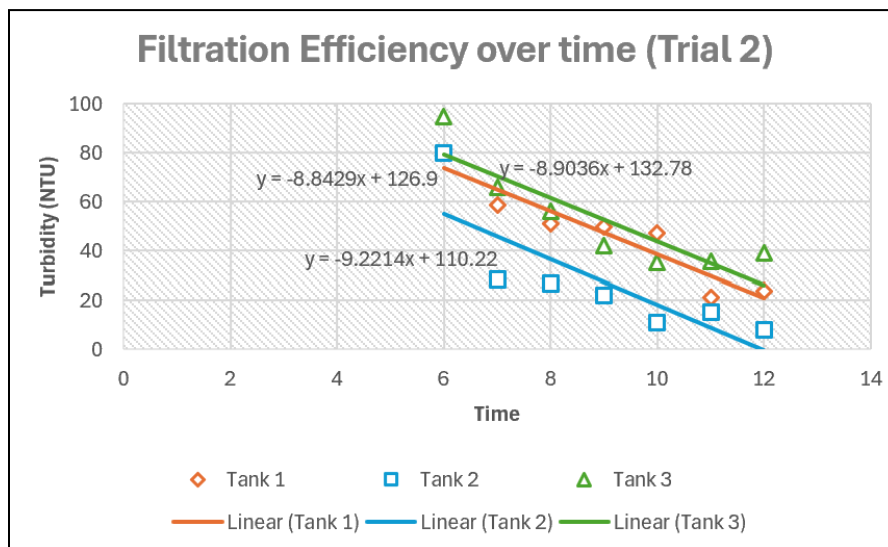
The data collection process spanned two weeks with two trials every six days. To simulate stormwater conditions, we poured 2.5 L of tank water using an up to down motion two times for each tank, then waited 30 seconds before collecting a sample for the turbidity meter. To inspect the water quality of the tanks, we used API Saltwater Master Test Kit which allowed us to test for pH, ammonia, nitrate, and nitrite in the water. Finally, we used a hydrometer to measure the salinity, which we kept at a constant value of 23 ppm, and a thermometer to measure the temperature of the tanks. To keep the water quality at an acceptable range for the oysters, we added nitrifying bacteria every three days, which are found in the oyster's natural environment, to ensure the oyster's survival.

The results of our experiment demonstrated that the tannins and mangrove structure indeed increased the filtration efficiency of turbidity. We carried out two trials to obtain more data to work with, however, the trials produced different results. The filtration efficiency of turbidity is measured by the turbidity difference over time/steepness of the lines. To achieve this, the slope-intercept equation of each line is displayed, illustrating the slope of the trend line of each tank. A steeper slope with a higher absolute value indicates a greater filtration efficiency while a shallower slope with a lower absolute value indicates a lower filtration efficiency. In trial 1, we observed that the tank with the steepest slope was Tank 3 which had a slope of approximately -12.986 NTU per day which suggested that Tank 3 was filtering out the turbidity the fastest (12). In trial 2, we observed that the tank with the steepest slope was Tank 2 which had a slope of approximately -9.2214 NTU per day which suggested that Tank 2 was filtering out the turbidity the fastest (13). This demonstrates that the two trials displayed varying tank performance and that Tank 2 & 3 filtered out turbidity faster than Tank 1 (control) in both trials.

(12). Filtration Efficiency over time (Trial 1)



(13). Filtration Efficiency over time (Trial 2)

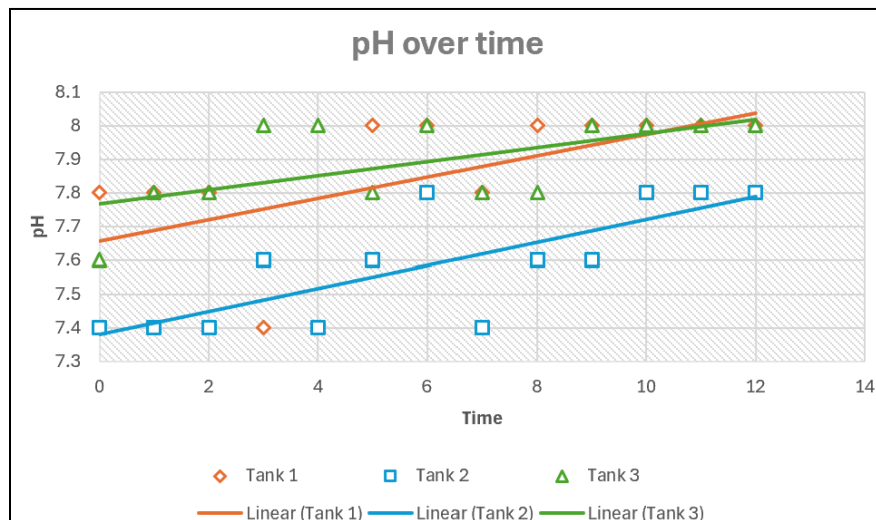


To test the correlation between the presence of the mangrove structure, tannins, and oysters with the turbidity levels of the tanks, we performed the Kruskal Wallis (H-test). Our data did not follow normal distribution so the Kruskal Wallis test was the best choice. It also allowed us to test whether our results were based on random chance or if there was a statistically significant difference between our tanks. For the test, we followed a p-value of 0.05, degree of freedom of 2, and a critical value of 5.991464547. The results of the H-test showed that H had a value of 11.34883721 which was higher than the critical value. This allowed us to determine that one or more of the groups differ from each other. We also tested the chi-squared distribution which told us how much the value deviated from the expected value. The chi-squared distribution resulted in a p-value of 0.003432664 which was less than 0.05. This allowed us to conclude that the results of our experiment was not due to random chance and that there was a correlation between the experimental variables and turbidity.

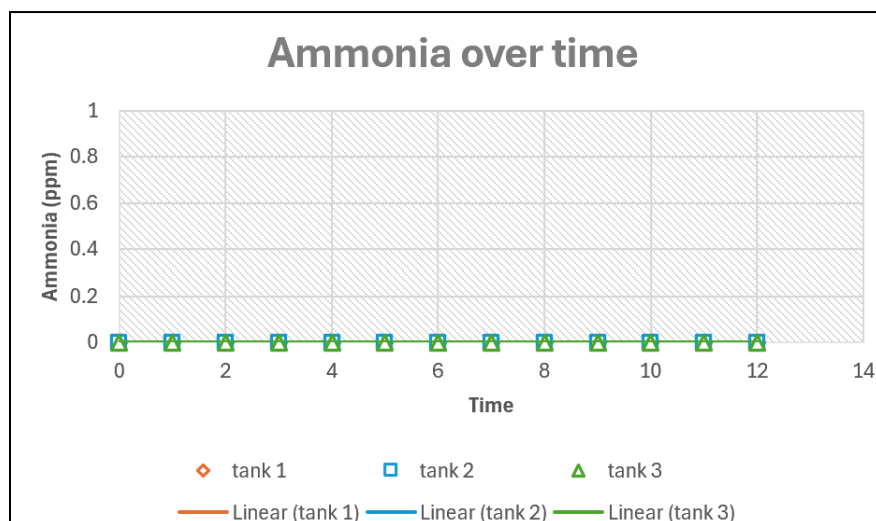
In addition to the measurements of the turbidity levels to determine the rate of filtration, we also conducted water testing in each of the three tanks everyday to determine the water quality. The results varied throughout each

tank, but the water quality could be directly correlated to the different factors we introduced such as the mangrove prototype, tannins, and kaolin clay. The basic water testing kit tests for pH, ammonia, nitrite, and nitrate which are all toxic in high levels to eastern oysters. The ideal range for each one of these compounds for eastern oysters are 7.8-8.4 pH, 0.1 ppm, 0.2 ppm, 16 ppm respectively (11). The pH observed was increasing throughout all tanks (14). This is most likely due to the kaolin clay as kaolinite, an abundant mineral in kaolin clay, is basic. The ammonia levels stayed constant throughout the experiment at 0 ppm (15). Similarly, the nitrite levels stayed constant at 0 ppm with the exception of Tank 2 which demonstrated a decrease in nitrite levels from its initial value (16). The nitrate levels all presented a decrease in all three tanks (17) which revealed that this experiment generally had a beneficial effect on water quality while filtering out turbidity and non-organic matter. From these results, we can determine that water quality has also improved, which increases the success of the using tannins and mangrove prototype as a solution to CSOs that will be impactful while also considering the water quality for marine ecosystems.

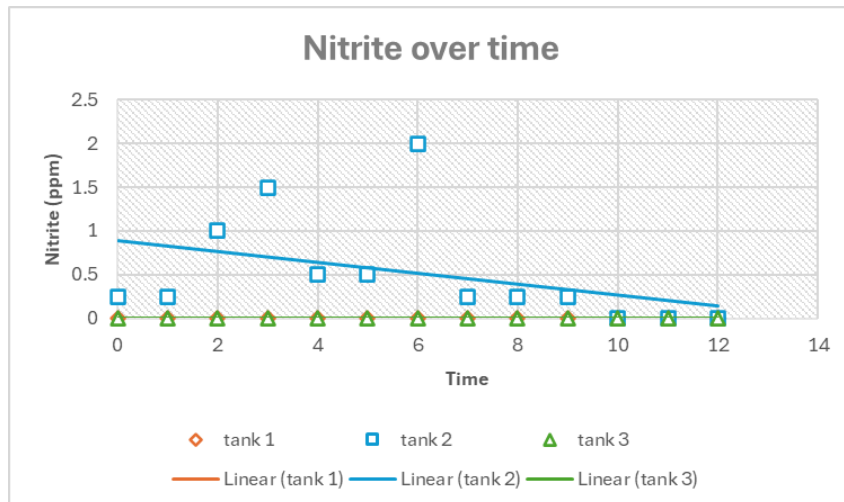
(14). pH over time



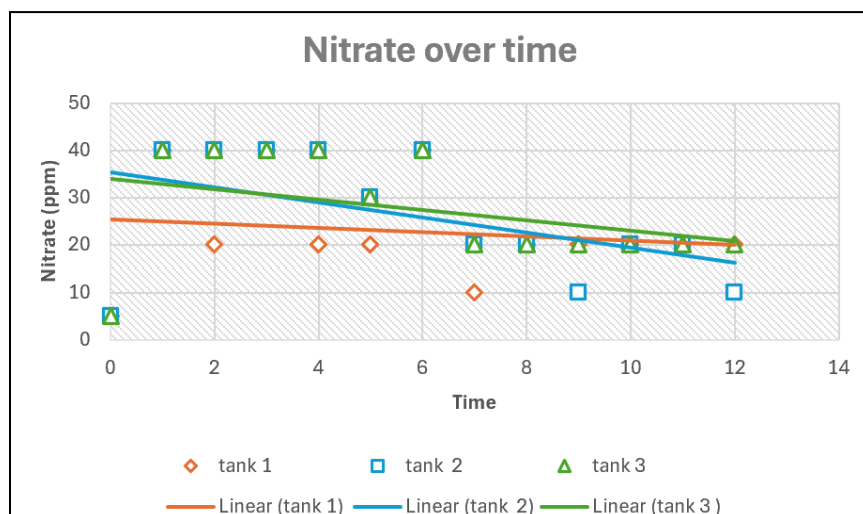
(15). Ammonia over time



(16). Nitrite over time



(17). Nitrate over time



Recommendation

We recommend implementing a mangrove-like prototype with oysters near CSO deposit sites to improve water pollution in waterways. Like the mangrove structure in our experiment, the mangrove-like prototype will be made up of a cluster of branches, but larger. Its dense structure and grooves will help catch turbid material in thus reducing the amount of pollutants in the water. Based on the results of our field research, the mangrove-like prototype and tannins are able to improve oyster filtration efficiency. The mangrove-like prototype was able to reduce the turbidity of the tank better than the control group. Our results also indicated a correlation between the turbidity levels and the mangrove structure, tannins, and oysters. Therefore, a mangrove-like structure with oysters can help reduce turbidity and pollutants in the water.

This recommendation would benefit people living in areas near CSO sites. As stated in our background research, long term exposure to polluted bodies of water poses a health risk, introduces pollutants into the water, and can harm oyster populations. By implementing mangrove-like prototypes near CSO sites, it can trap pollutants and

reduce risk of disease. It can also act as a buffer, capturing some of the pollutants before the oysters filter. We want to make waterways cleaner for the residents living near these CSO sites and also help remediate the environment. Many CSO sites are heavily polluted and can be dangerous to live near. By implementing this system, we hope to alleviate this issue more so that the waters can return to safe levels for the citizens and the environment.

There are potential obstacles that we may encounter when implementing our recommendation. Before implementing our recommendation, we need to find and contact CSO sites and ask for permission to work at those sites. Many CSO sites are heavily polluted and may be hazardous to work with, so we need to follow safety procedures. During our implementation, we will need to figure out how big the prototype needs to be so that it can be the most effective in capturing pollutants. We will also need to figure out how to place the prototype into the water and accurately collect data. We will also need to figure out the extraneous variables that will affect the functionality of the prototype as well as how this affects the marine organisms living there. After our implementation, we will need to figure out whether our prototype needs adjustment. We will also need to figure out if this recommendation could be implemented at other CSO sites. Furthermore, there might be government officials who might oppose our recommendation. The government officials may not want to fund a program of installing a CSO mitigation system as there has not been many studies done on this topic. There also has not been data on the actual implementation of this recommendation in a CSO site. Additionally, it will be costly to implement this system wide scale to the many other CSO sites in NYC. Our idea has not been implemented before possibly due to the methods already being used to clean water. In NYC, there are wastewater management sites and laws that have reduced some of the runoff, but there are still many pollutants entering the waterways. Furthermore, mangroves have been known to be good filterers; however, in NYC mangroves cannot be planted due to the cold weather. Therefore, we hope that our recommended solution will be able to significantly reduce the amount of pollutants in the waterways, assist oysters in filtration, and improve water quality in order to help the people living near CSO sites and also improve the environment.

Implementation

The results of our experiment concluded that our recommendation can be implemented. To implement our recommendation, we first reached out to a few non-profit organizations who work near CSO sites to see if we could work together to implement the recommendation. We decided to reach out to the Billion Oyster Project, Big Reuse, and the Gowanus Canal Conservancy (GCC). Some had not responded and some were not able to assist us with our issue. However, we did get a reply from the Youth Programs Senior Manager at the GCC, Auriela Casey, who responded to our request. We started to work with Auriela to see if our plan can be implemented in the canal. Secondly, we developed a procedure to implement the recommendation in the canal. We first will collect branches at a local park and arrange them in a clustered position. Next, we will bring the prototype to the GCC and the GCC will place the mangrove-prototype into the canal. Then, over the summer, we will come every week for a month to perform water quality tests on the water not near the mangrove-prototype and one near the mangrove-prototype. Because the water is heavily polluted, there are very few oysters in the canal thus we cannot rely on oysters to filter the water. However, there is another bivalve organism in the canal called the Atlantic Ribbed mussels, who are

already adapted to the conditions of the canal and are filterers as well. We plan to place the prototype near the mussels so that the mangrove-prototype can act as a buffer for the mussels. To determine if our implementation will be successful, we will monitor the water quality to see if there are any changes after the mangrove-prototype has been implemented.

Although we have only made an outline of our plan so far and have not confirmed a partnership, we aim to work with the Gowanus Canal and other CSO sites in implementing this recommendation to help reduce the pollutants in the canal. If we are able to carry out this experiment and it is successful, we will make a simulation based on our data to predict the effectiveness of this recommendation over time. Additionally, we will also improve upon the prototype based on the data collected to make the prototype more effective. Lastly, we hope that, in the future, we can implement this recommendation to other CSO sites in NYC to fully mitigate the issue of stormwater runoff.

Financial Implications

In implementing our recommendations, we have considered the following items on the table below. These resources will be used to raise awareness and put the recommendation into action in CSO sites such as the Gowanus Canal and Gowanus Bay.

Item(s)	Connection to our Implementation	Costs	Benefits	Funding Source
Awareness Posters	These posters will be placed in public spaces such as the beach to raise awareness about the grave issues that follow a storm/heavy rainfall event.	~\$15 per poster, need to find where the posters can be placed.	People will know more about this issue and advocate for changes, volunteer themselves or provide support for the cleansing effort.	Donations from people or a fundraiser.
Mangrove Saplings	Mangrove saplings will be planted along CSO sites to assist in filtration as our results revealed that the mangrove prototype performed well in filtering out	~\$10 per sapling, and may damage infrastructure if grown incorrectly.	CSO sites will have improved water quality.	Donations from people or a fundraiser.

	the kaolin clay and other compounds such as nitrate.			
Website	The website is going to contain information about our implementation and contain information such as volunteering and donations that go towards our implementation.	Time to make and maintain the website.	People can easily access and find a way to join us in improving water quality since they can obtain information about us on the site.	It's free to make, and we're going to make one.
Oyster cages	These oysters cages are where the oysters will be in, and it protects the oysters from other marine species, and it is easy to monitor the conditions of these oysters when it's in tank. Oysters help filter out water and is essential for the CSO filtration effort.	~\$285 per cage, and takes up space in the water.	These cages will provide a safe environment for the oysters, and they can filter out plankton, algae, and other compounds.	Donations from people and fundraiser.
Volunteers	Volunteers can assist us in setting up oyster cages and planting mangrove saplings.	\$17 per person minimum wage if recruited or if they're volunteers, it can be free.	The implementation can be carried out much faster in order to address this issue that is in need of urgent attention.	People learn about the opportunity to assist through the website. Most likely, the people will be volunteers

				who will volunteer their time for free.
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Conclusion

Stormwater pipes are an example of one of NYC’s worst infrastructure as it is largely inefficient. Increased rainfall due to climate change has caused frequent combined sewage overflows (CSOs), releasing polluted stormwater into waterways that impact water quality and puts public health at risk. Despite policies being enforced in an attempt to alleviate this issue, they have been largely ineffective and calls for a greater solution that does not involve disrupting marine life. Efforts by the Billion Oyster project aimed to restore oyster populations and improve water quality, however, more research must be done alongside what they are doing in order to find an environmentally friendly solution that does not interfere significantly with marine life. We believe that by installing Eastern oysters and mangrove prototypes in CSO deposit sites, it would significantly reduce turbidity and improve water quality by filtering pollutants as we have found that there was a statistically significant difference between the performance of tannins, mangrove prototype, and the control variable showing that mangroves and tannins performed better than the control. Communities affected by CSOs are also able to implement this solution of placing mangroves and oysters near CSO deposit sites to improve their water quality, public health, and reduce the risk of gastrointestinal illnesses. Mangroves could also stabilize the shores by absorbing excess runoff. However, some areas may not be able to implement this solution due to lack of funding or lack of space to grow mangroves as it is a concern that mangroves may damage original infrastructure. During the drafting phases of our experiment, we have developed independence by reaching out to different agencies such as the Big Reuse, GCC, and the BOP for partnerships to address this issue in our community. In the future, we will strive to implement our solution by testing the effects of mangroves and bivalves such as oysters in one of the dirtiest CSO sites, the Gowanus Canal.

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