Campus Climate Lab

Improved Seabin Technology: Charles River Cleaning Initiative

Summer 2023 Report

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Abstract

Water pollution has become an increasingly pressing issue affecting human health and the environment. Rivers and water bodies, such as the Charles River, are vital resources that provide clean water for drinking, recreation, and habitat for aquatic life. Unfortunately, due to human activities, these water bodies have become severely polluted by non-degradable plastic litter. Its presence in these water bodies is a common issue and is known to harm aquatic life and contaminate the water.

The proposed research project aims to address this issue on the BU campus territory by designing a water surface litter collector, based on the Seabin Project, that is adaptable to shifts in water level, energy-free, and effective at collecting plastic while being safe for marine life. The project is imperative as it aims to make Charles River cleaner and safer for people and animals, contributing to a more sustainable and environmentally friendly campus. In addition, our work aims to optimize the Seabin Technology by introducing an energy-free pressure pump, making it versatile for alternating water levels, and fixing its biggest problem: a manual collection of litter is still more effective than usage of engineering devices for it.

We plan to implement the water bin by the docks and lagoons at the Boston University's campus where there are increased concentrations of plastic and other litter. The water bin will consist of a bin itself with an open end just beneath the surface of the water, a pressure pump that ensures constant flow through the bin, and a fixture mechanism that moves the bin according to the water level.

While focusing on improving the engineering design of cleaning technology, we also pay great attention to the sustainability issue. Not using toxic chemicals and plastic in manufacturing the device is a priority for us, and water taken from the river should be promptly returned without exposure to heat hence the work of the pressure pump does not pose a threat to algae or microorganisms. We will also conduct additional research on keeping animals from getting harmed by the water bin.

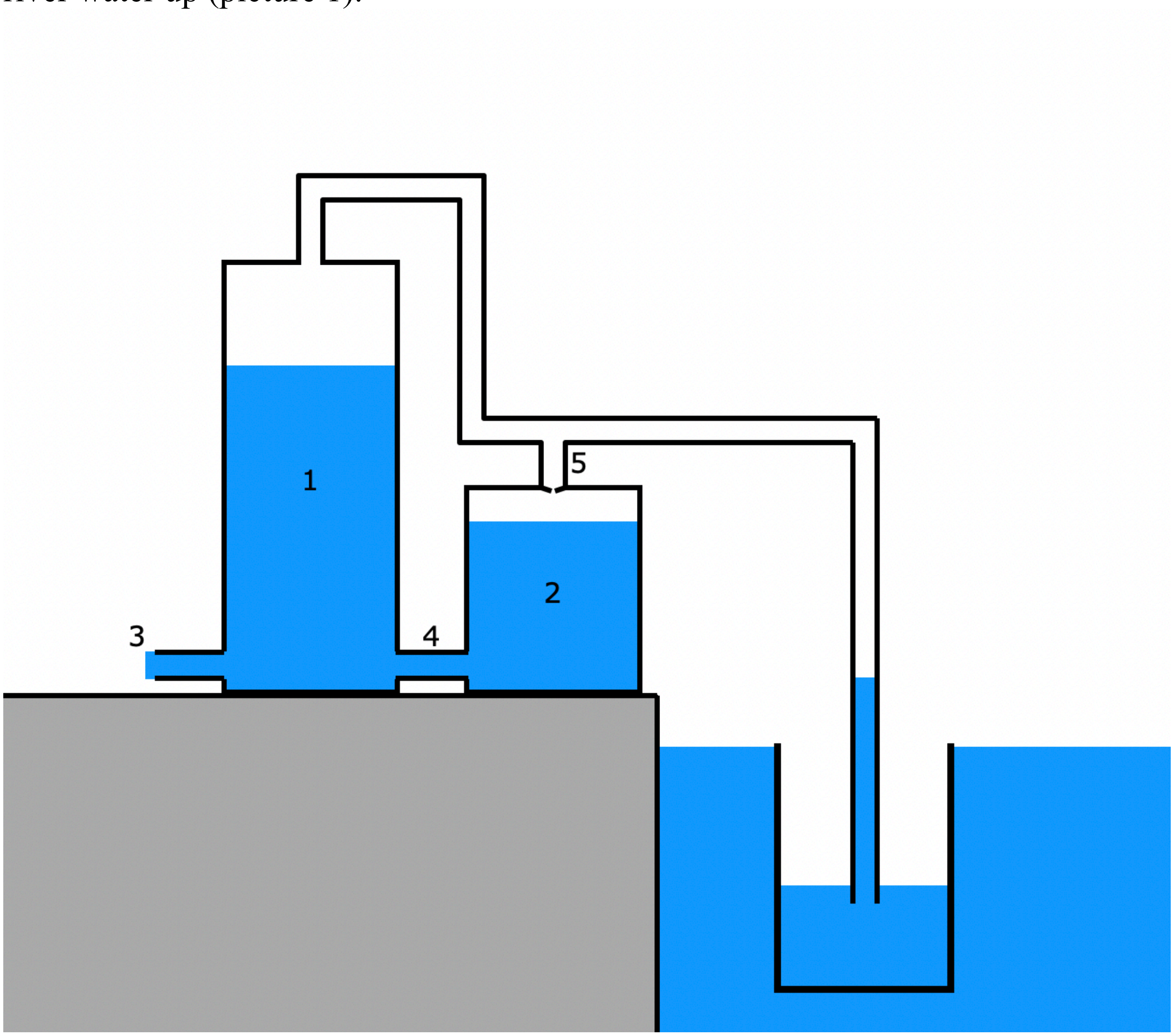
As we are researching ways to improve the water bin and make it valuable for the campus, we will explore the possibilities of integrating additional filtering technologies that can extract some of the unwanted chemicals in the river. As the biggest threat to the Charles River is stormwater and all harmful chemicals it carries from the city into the river, we can test implementing a water bin close to a sewage discharge and see how effective this solution can be.

In conclusion, the proposed research project is crucial for promoting a cleaner and healthier water environment at Boston University and beyond. At the same time,

the work covers multiple fields and promises to give valuable experimental data on the efficiency of litter collection and energy-free pumps.

Methodology and Results

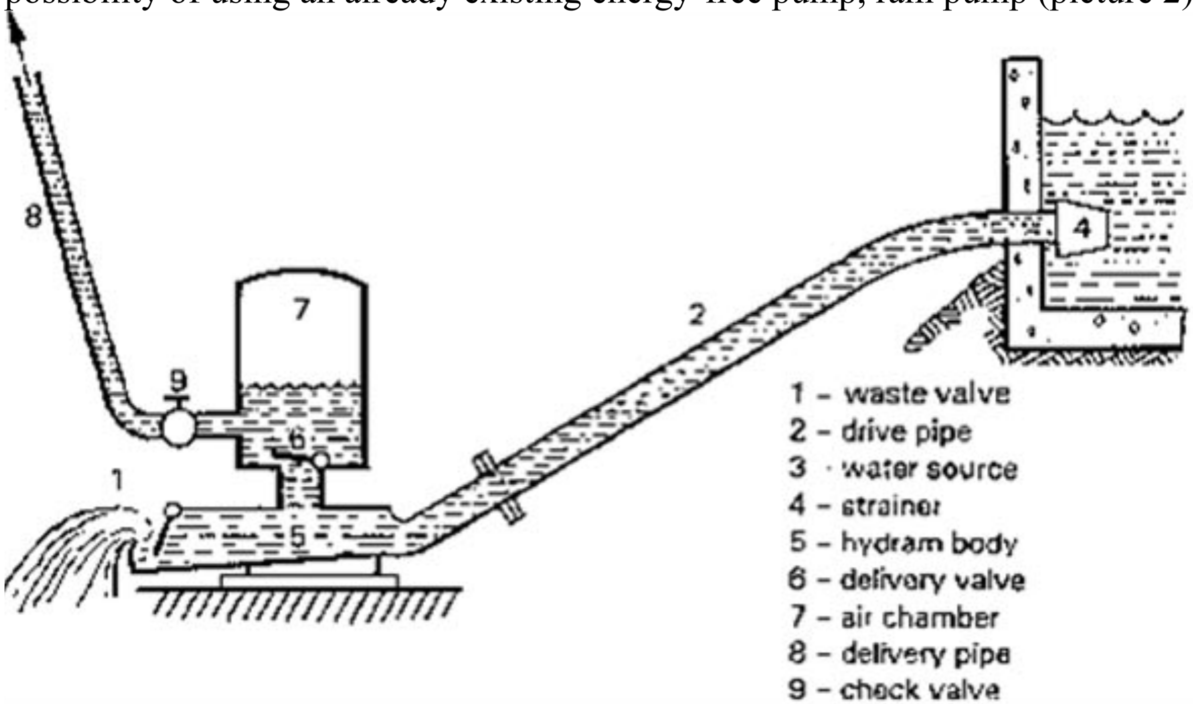
The first point we've worked on is energy free pump calculations (June 2023). The idea is to build a water pump that works due to sealed tanks not fully filled with water. The most promising concept was a system consisting of 2 sealed water tanks of different water levels that when connected on the bottom, pump the river water up (picture 1).



Picture 1. Pump System Scheme

First, outlet (3) and a connecting pipe (4) are opened leading to air pressure in the first tank decrease to around 0.9 atm which is less than in the second tank. However, this pressure isn't sufficient to pump water to the height of the first tank but enough to pump it to the height of the second tank. To make the system work, a pipe is required that connects tank 1 and the Seabin while being connected to a check valve (5) that leads to tank 2 and makes sure that air pressures of the tanks don't mix. The check valve is crucial for keeping air gaps of tanks separated in order to pump water. However, even if we succeed at making such a check valve that its physical properties would allow us to open it towards the side with a greater pressure (air gap of tank 2), air from tank 2 would slip into the pipe and therefore to the first tank. Thus, gradually air pressures in the tanks would equalize and disable the pump. This case (having air as a working body) requires constant maintenance, and power (such a pump can produce mass flow rate up to 3 kg/s) doesn't justify the cost. Although such an energy-free pump is implementable, we won't use it for its ineffectiveness.

After the described approach proved itself to be inefficient, we researched a possibility of using an already existing energy-free pump, ram pump (picture 2).



Picture 2. Ram Pump Design

Even though ram pumps are available in the market for an affordable cost, its engineering characteristics make it inapplicable: placing the pump beneath the source of water demands additional construction works.

In conclusion, as research into energy-free pumps revealed their ineffectiveness or inapplicability in our case, we move on with the project considering using an electric pump as all other Seabin devices do.

While we were working on the pump research, we've done work on collecting information and data sheets from aquatic life professors and organizations that lead cleaning projects in water bodies across the North America (Florida, Massachusetts, Torornto).

Most important input we have received from professors Wendy Heiger-Bernays, Phillip S. Lobel, and Maia Mcguire, University of Florida and Florida Seabin Project (Sea Grant Florida). Also, we have received insights from Charles River Watershed Association (CRWA) and University of Toronto PortsToronto Trash Trapping Program.

Consultations

The first insight on Charles River problems was provided by Max Rome Ph.D. at CRWA. According to Max Rome, the biggest threat to the river is stormwater with its acids and chemicals. While there are several locations (picture 3) polluted by plastic debris, they don't threaten aquatic life and people as much as stormwater does. CRWA and other entities fight with chemicals in stormwater, and this work demands considerable investments and methods that cover huge volumes. As a result, Seabin Technology is inapplicable in this case because chemicals spread through the entire water body, not just its surface.

Picture 3. BU Sailing Pavilion

Professor Wendy Heiger-Bernays, a clinical professor in the Department of Environmental Health at the BU School of Public Health, focuses her research on the impact of industrial chemicals, consumer products, and pharmaceuticals present in water and waste streams on human health. We engaged in an early-stage conversation with her to gain insights into filtration methods and strategies to prevent aquatic organisms from entering our device. During our discussion, Professor Heiger-Bernays emphasized the prevalence of harmful substances in today's water, such as PSAF.

We had the opportunity to accompany her along the Charles River, where we utilized her specialized equipment to assess water quality, acidity. Multiple testing points along the river yielded consistent results. Professor Heiger-Bernays noted that water quality tends to decline after rainfall or drainage system spillage. Additionally, she underscored that while Boston's water bodies may appear free of large plastics and debris, harmful chemicals and oils still pose significant environmental challenges, urging us to shift our focus accordingly.

In order to solve the problem of the Seabin being harmful for aquatic animals, we reached out to Phillip S. Lobel Ph.D. The conversation with Professor Lobel began over the best methods to deter marine life to prevent fish from being pulled into our Seabin; however, the major takeaway from the discussion was to cater our design specifically to the environment where the Seabins will be installed. Motion detectors and other sensors were disregarded due to biofouling processes that would eventually cover and disrupt the technology. Instead, Professor Lobel suggested that the placement of the bin itself was key. He recommended installing them in more shaded, less illuminated parts of a harbor, and that trash collection would be optimized if knowledge on the ocean's topography and currents of the area were known. He also made sure to address the fact that the bins would not be allowed in areas that hosted endangered species as avoiding any ecological disturbance at all would be unachievable. Professor Lobel greatly emphasized the need to precisely define a problem. He believes our original approach was too passive, saying that we were looking to find a problem where we could use our solution, instead of targeting the problem and tailoring our design to solve it to the utmost degree.

In July, we were in contact with University of Florida Seabin Project and Maia Mcguire Ph.D. who shared with us their experience and data. Throughout these conversations and data exchange, we discovered main flaws in the Seabin Technology. First, constant submergence in water leads to biofouling (picture 4). Especially suffers the space between 2 cylinders (main body and yellow moving cylinder) leading to maintenance and operation difficulties. Second, the catch bag (the filtering net) often allows smaller pieces of plastic or plants go through it, thus clogging the pump. Third, and also supported by Professor Lobel's words, the location where the Seabin was installed was an active habitat of different aquatic life, and everyday several fish, prawns, or other animals would fall in the catch bag and mostly die there.

Nonetheless, there were some positive outcomes in the Florida Project. Oil pad placed in bottom of the Seabin proved to be extremely useful when a nearby boat would have an oil leakage and oil spill. Since oil stays on the surface of water, it is perfectly filtered by the Seabin that only affects the upper layer of water.

Picture 4. Seabin Installed by a Canadian Project (Georgian Bay Forever)

While Florida's project was unsuccessful in term of numbers of filled animals, there are still successful projects that don't harm aquatic life and build a useful database on plastic pollution. One example is University of Toronto PortsToronto Trash Trapping Program. In 2022 their 10 seabins collected around 18 kg of plastic trash which is successful for Seabin projects but still drastically less than what other devices can collect at the same time. For example, the skimming technology implemented by Trash Trapping Program collected around 100 kg of plastic pollution (TRAPPING TRASH IN THE TORONTO HARBOUR: 2022 DATA SUMMARY).

Another report we found useful is a report by volunteers in Auckland, New Zealand. According to their data, around 99% of the collected debris was organic, leaves or branches.

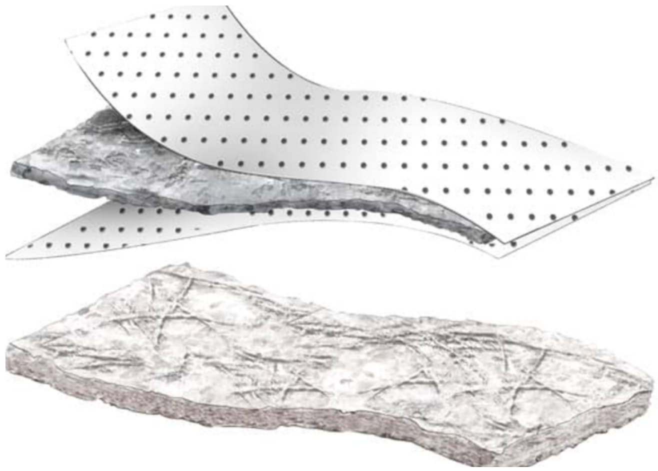
Discussion and Oil Spill Removing Device

Having analyzed the data sheets, reports, current problems of Charles River, and valuable insight from experts, we came to a conclusion that Charles River doesn't require a Seabin for its inability to clean the river. Also, Seabin doesn't noticeably collect microplastic which doesn't float on surface of water.

However, our research led us to a new device that will remedy all original problems of seabins, such as biofouling and threatening to aquatic life. Since the Seabin managed to successfully clean the oil spills in docks, we are currently considering designing a Seabin of lesser size (to reduce cost and ease maintenance) without a catch bag but with a net on top of it to prevent any animals or debris going in. This device will be removing fuel and oil spills from boats in ports and docks. This device won't be used for considerable amount of time to prevent biofouling: it will be submerged in water when an oil spill accident occurs. As there is not many devices that eliminate oil spills, adjusting the Seabin's design can be a viable solution.

As a starting point in making such a device, we are researching oil pads that will be used.

Shifting our focus towards the removal of oil and chemicals from water required the exploration of new filtration methods. Currently, we are investigating the application of oil and chemical-absorbing powders and granules. Traditional oil absorbent pads typically comprise three key components: Polypropylene (PP) (picture 5), a synthetic polymer with oil adsorption properties; natural fibers like wood pulp, cotton, or flax fiber; and synthetic fibers including acrylic, nylon, or polyester. In contrast, granular sorbents are fashioned from either recycled or natural, biodegradable materials. Common choices encompass Corn Cob, Peat Moss, Gran-sorb, and Super sorbent.



Picture 5. Polypropylene Layer on Oil Pads.

It's important to note that granular sorbents may present certain limitations, including potential ineffectiveness and messiness when used for spill cleanup. We must delve further into specific research areas before deciding on the components to utilize. These considerations include the type of spill we may encounter, the time available for response, and whether residual cleanup will be necessary after spill removal.

Our research project set out initially to address the pressing issue of water pollution in the Charles River near Boston University's campus. Our main objective was to design a water surface litter collector, known as a Seabin, that would be energy-efficient and highly effective at collecting plastic debris.

However, we quickly were faced with the obstacles of inefficiencies and harmful impact, so we sought guidance from professors and experts in the field. These consultations were instrumental in shaping our project's direction. We realize that if manual trash collection is more practical, we should instead focus on a different critical issue. Therefore, we reevaluated our project's objectives. We now intend to develop a Seabin with a design primarily focused on skimming oil from the water’s surface.