Fluvial Instrument for Sample Harvesting (F.I.S.H): Design of an Aquatic Device Aimed to Clean Latin American Waters

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Abstract – This paper focuses on the design process of the Fluvial Instrument for Sample Harvesting (F.I.S.H) to identify the presence of the contaminate known as polychlorinated biphenyls, PCBs. The F.I.S.H is a mobile autonomous aquatic device that is capable of collecting soil samples underwater to be tested for PCBs. With the confirmation of this contaminant being present, bodies of water that have been neglected for years can begin efforts for PCB removal. This project is aimed at countries in Latin America and parts of South America where PCB removal efforts have been missing for the past decade. The F.I.S.H is programmed with an Arduino Uno, pressure sensor, stepper motors, and a 12V power supply.

Keywords – polychlorinated biphenyls (PCB), contaminant, harvesting, Arduino, aquatic, Kakute

I. INTRODUCTION

Large companies introduced polychlorinated biphenyls, also known as PCBs, to aid with the production of coolants, lubricants, hydraulic fluid, and more. The compounds were widely used for their non-flammability, low reactivity, high boiling point, and electrical insulating characteristics. There are several types of PCBs that were mass-produced, with variations that are denoted with the name “Aroclor.” The number next to the PCB signifies the chlorine content by weighted percent, for example Aroclor (PCB) 1242 has a chlorine content of 42% [2]. These companies would later dump tons of these chemicals into various waterways without considering the damage it would cause as time went on. The United States had manufactured this organic chemical from 1929 until 1979 but was outlawed after being repeatedly linked to health risks to humans and the environment [1]. The adverse effects this compound had, proved to damage ecosystems, taint drinking water, and posed a threat to human health through the consumption of fish. When fish and other organisms are exposed to these compounds, the compounds are absorbed by the organism and become more prevalent. The PCBs carried by the fish are then consumed by humans that could later have negative effects. Due to this, many bodies of water have strict regulations on the quantity of fish caught at a given location [3]. Currently methods to identify these compounds are limited because it is very expensive to collect samples and filter out the harmful chemicals. It is also inefficient because the most common method requires stationary tanks, meaning that all resources go to one body of water at a time. As a result, less waterways can be tested and as time goes on the compounds remain in our waters damaging the ecosystem. Being able to collect soil samples and test waters would allow companies to pinpoint specific areas and see which ones require immediate attention. This way more time can be spent taking action rather than letting PCBs stay in our waters.

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II. NEED STATEMENT

There is an imperative need to test waters for PCBs. These toxic manmade organic chemicals have been present in our freshwaters, such as rivers and lakes, since the 1920’s. It is essential to test these bodies of water through the process of collecting soil samples since there is significant PCB pollution in the waterways leading to contaminated drinking water and toxic fish consumption. These chemicals are known to cause harm from human ingestion. It can cause liver damage, bad acne, and even cancer in dire cases [4]. Creating a more efficient way of collecting soil samples to inform companies about polluted freshwater would reduce time to identify organic molecules, decrease costs, and omit the need for heavy machinery. As a result, the main task of the F.I.S.H, is to collect multiple soil samples from different locations to determine the presence of organic molecules in the water. With the compact and efficient process completed by the F.I.S.H this task can be accomplished.

These affected water sources must be preserved and properly tested. For that reason, an automated process that wouldn’t need immense machinery or limited to one area would improve efficiently in water quality testing and sample collection.

A. Environmental Impact

The purpose of F.I.S.H is to speed up the process of identifying PCBs to differentiate contaminated areas, giving companies and agencies more time to act on this problem. These chemicals pose a threat to the fish we consume due to the solubility compound of the fats, which becomes more potent in the fish. High levels of potency make PCBs more prevalent in fish which could be toxic after consumption. Testing locations occur one at a time because of the stationary systems used to detect organic molecules and could take months or even years to determine if a location is polluted. Implementing this autonomous device would make collecting and testing samples more accessible. Furthermore, different locations could be tested at a faster rate and would make monitoring the bodies of water easier. The materials used are also considered in order to preserve the water and the organisms around. In doing so, more time can be spent cleaning contaminated areas to ensure that the waterways stay clean as well as the organisms that live in and around the waterways.

B. Economic Impact

The objective of this project is to test waters for toxic manmade organic chemicals in a more efficient way, in an effort to reduce costs. The method commonly used to detect and filter out these PCBs is expensive and takes extensive time to produce results. It is said that the Hudson River had a cleanup operation from 2002-2005 and from 2009-2015, which cost the EPA and General Electric Company (GE) $20.5 million, with total cost estimates of over $24 million [5]. This device would drastically lower costs for companies due to its mobility and size allowing to pinpoint areas of contamination. Environmental organizations also play a significant role by overseeing cleanup operations and ensuring that the quality of work is not jeopardized because the company wants to save on costs. By implementing F.I.S.H, environmental agencies would be able to access multiple samples collected from different locations to find contaminated areas and continue to monitor them afterwards.

III. MARKET RESEARCH

Based on the market for sample collection equipment is limited to expensive ($1500-$2000) and stationary facilities that use large water tanks [6]. This stationary practice causes limitations for testing water quality in smaller bodies of water that directly affect communities that rely on local water sources that may be contaminated. The F.I.S.H solves this issue by using simple engineering principles and equipment to securely collect soil samples, similar to the water tanks, but with the advantage of mobility and low-cost production of approximately $320 USD.

IV. AUDIENCE

The F.I.S.H is aimed at countries in Latin America and parts of South America that have been known to be negatively affected by the presence of PCBs. Many of the communities and cities rely heavily on these water sources, however these sources may be unknowingly harmful due to lack of testing. For example, in the waters of Santos Bay, State of São Paulo, Brazil there have been tests completed that show the presence of toxins (PCBs) in crabs [7]. The F.I.S.H would be a possible solution to this problem with its mobility and ease of sample collection.

V. ENGINEERING REQUIREMENTS

It is crucial that the F.I.S.H meets the following requirements to ensure that it can function both mechanically and as a submersible:

Waterproof: The casing of the F.I.S.H must be waterproof and leakproof to ensure that the internal components are safe from water damage.

Compact: The planned dimensions are 12x6in for the overall casing. Along with a total weight of roughly 3lbs.

Environmental Conscious Material: Abiding by the Environmental Protection Agency (EPA) regulations, selected materials must not be harmful to the user or environment [3].

Obstacle Avoidance: Through the use of a waterproof ultrasonic sensor, obstacles like fish or debris can be avoided as the F.I.S.H sinks into the water

Efficient Collection: The drill mechanism will be capable of both penetration and collection when in contact with the soil once at ground level when underwater.

VI. BUDGET

The estimated total cost of the F.I.S.H can be found in Table 1. The estimated cost runs at approximately $320 USD. These parts are the necessary components to manufacture and ensure assembly of the robot.

TABLE 1
COMPONENT PRICING

Equipment	Units	Unit Cost
Arduino Uno	1	$20.70
12V Rechargeable Battery	1	$35.00
Easy Driver Stepper	2	$33.00
Linear Stepper Motor	2	$57.98
9V DC Motor	2	$13.78
Syringe	1	$2.00
Pressure Sensor	1	$25.00
Camera	1	$15.00
Threaded Rods	2	$5.78
O-Rings	1	$8.99
Resin	1	$35.00
Acrylic Plastic (Cylinder)	1	$17.99
Acrylic Plastic (Sheet)	1	$8.99
Water Resistant Coating	1	$5.99
Ultrasonic Module	1	$13.99
TOTAL		$317.18

VII. DESIGN CONCEPT

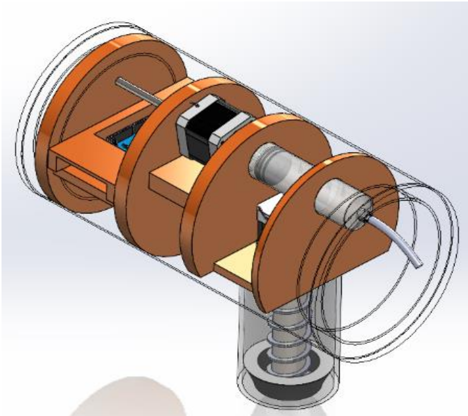

Figure 1: Isometric view of F.I.S.H

A. Mechanical

1) Motion

The ability for the robot to move through the water is an obstacle that must be faced head on. The idea of this motion will come from two different 9V DC motors. These 9V DC motors will counter-act each other to remain in equilibrium. When the motion is forward, one will spin faster than the other to propel the robot forward, and vice versa to go backwards.

For the robot to move up and down, a submarine approach will be taken. Water will be collected via suction with the syringe to submerge the device to its appropriate depth. When the robot reemerges, it will be done so by pushing the water out and coming back to the surface. This is pulling and pushing motion within the syringe will be accomplished with a 12V stepper motor connected to the rubber stopper. The rotational and linear motion created by the stepper motor and buoyancy are key factors in the mechanical design of the F.I.S.H.

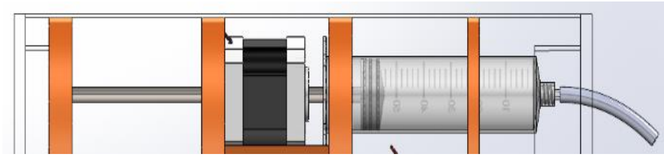

Figure 2: Syringe system in F.I.S.H

1) *Drill Mechanism*

The drill mechanism will be based off an auger drill powered by a 12V stepper motor. Like an auger drill, this mechanism will extend 1in, rotate into the soil, pulling soil up along the shaft of the drill as it further digs into the ground. The soil will be collected by falling off the shaft and caught in a mesh net that is hung above the perimeter of the black stopper. The mesh will be porous enough for water to fall through but small enough to hold the collected soil.

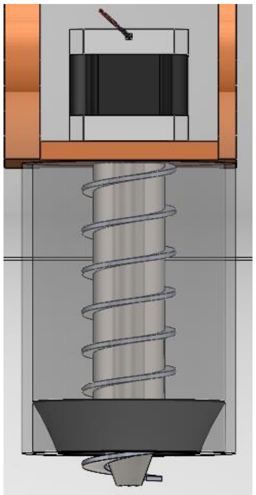

Figure 3: Drill and soil collector in F.I.S.H

B. Electrical Design

The electrical work will be based off the Arduino Uno. The Uno was chosen due to the number of pins and the powerful capabilities of the microcontroller. A various number of sensors, actuators, and motors will be directly connected, therefore a powerful microcontroller such as this one becomes the best option for usage.

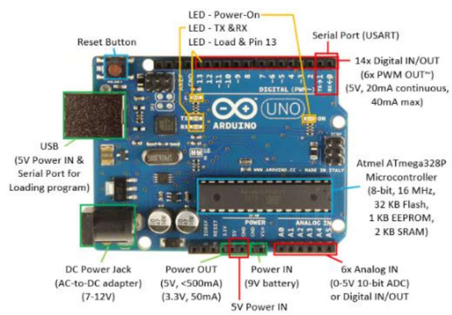

Figure 4: Arduino Uno Microcontroller

1) *Pressure Sensor*

MS5540C is a water depth micro barometer that uses low voltage and low power. The 3-wire interface connects all communications with the micro controller. To protect the sensor, a gel protection is applied to provide water protection up to 100 m. Measuring and recording pressure is significant since pressure is linearly correlated to depth. Depth can then be calculated using the pressure recorded, the density of freshwater, and the acceleration due to gravity.

Figure 5: MS5540C pressure sensor

2) *Ultrasonic Sensor*

This sensor will be used for obstacle avoidance. It will calculate the horizontal displacement between the device and any obstacle or organism in order to avoid them. In turn reducing the chances that the device becomes damaged or potentially harms wildlife.

Figure 6: Ultrasonic sensor for obstacle avoidance

3) *Stepper Motors*

These motors will be a crucial part of the device allowing for the intake/outtake of water into the system as well as operation of the drill mechanism. Controlling the water displacement in the system will permit the device to sink or rise. The second motor would be the main component of the drill mechanism. It would directly push the drill into the soil and collect the sample. These motors will be powered through two Easy Driver stepper motor drivers. This allows the stepper motors to be powered and programmable by the Arduino Uno.

Figure 7: 12V stepper motor for syringe and drill

4) *Display*

An OLED display module will be used alongside the pressure sensor for testing purposes, to ensure the proper testing depth of 13ft is reached. As the device submerges, the display will show the pressure as it increases and reaches the ground. Once it reaches the test site it will record the pressure at that level and remain there until it is reset manually.

Figure 8:OLED display for pressure level

C. Updated/Current Design

Figure 9: Isometric View of Current Iteration of F.I.S.H

1) Motion

In this complete redesign for the F.I.S.H the mobility for the device will come from two types of propellers that are remotely controlled. Two propellers on the back will allow for vertical movement at a speed of 1.56mph and two propellers on each side will create horizontal movement and rotation at a speed of 0.76mph. Each of these propellers are powered by 9V DC motors that are connected to a set of differentials that will turn the side propellers.

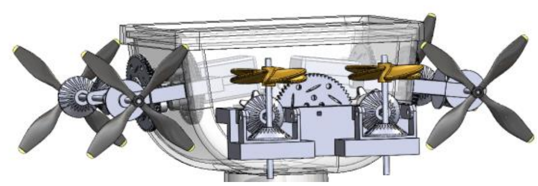

Figure 10: Back and side propellers with differentials

2) Updated/Current Drill Mechanism

The function of the drill mechanism remains the same, however after troubleshooting it was decided that a 750KV brushless motor (BLDC) would result in a smoother rotation, as compared to the choppy rotational pattern of a stepper motor. As far as the design is concerned, it was given teeth towards the tip to ensure that breaking through the first layer of soil would be accomplished with ease. The flanges that wrap around the shaft of the drill have been extended to hold more soil securely.

The mechanism for ensuring that soil is not lost on the journey back to the surface is still in development. As for the current progress, the drill has a collapsible cover that protects wildlife from coming in contact with the drill will it is in action and retracts as the drill enters the soil.

Figure 11: Updated auger drill design with drill cover

D. Updated/Current Electrical Design

With the use of a Kakute flight controller the BLDC motor for the drill and Dc motors for the propellers can be directly controlled in terms of torque and direction. This flight controller also tracks changes in pressure and orientation, removing some of the electrical components from the previous design.

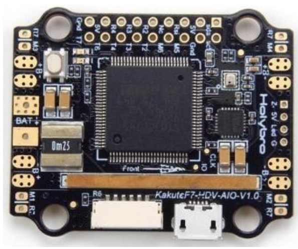

Figure 12: Kakute flight controller

VIII. PRODUCT EVALUATION

The F.I.S.H is currently under development in terms of producing a working prototype, with the assembly and troubleshooting of the electrical components. Considering that the authors reside in New York State, the tests will be conducted in the calm lakes of Sunken Meadow State Park on Long Island. Once samples can be successfully collected, the soil sample will be sent to a water quality lab for testing of present contaminants. If the process is successful, this procedure can be replicated with teams in South America, specifically in the area of Santos Bay, State of São Paulo, Brazil. This is due to the history of PCB presence, which would ensure that testing is accurate and reliable.

IX. CONCLUSION

The F.I.S.H is a mobile aquatic autonomous device that is capable of collecting soil samples underwater for detection of PCBs. Although sample collection and quality control are common practice in major areas, there is a lack of versatility in mobility when testing for contaminants in larger bodies of water. Especially in areas that lack technological and financial support in owning water treatment facilities. The F.I.S.H makes for an affordable and simple to use device that can be incorporated in low income or difficult to reach communities in Latin and South America that may have contaminated water sources.

As production for this project is underway some ideas that may be implemented in the future are ways to improve weight distribution with a new drill mechanism that would allow multiple soil samples to be collected at once. This would make the test sample much larger, resulting in more reliable results. Another idea that is planned is to finalize a future iteration that can be remote controlled in all aspects, from vertical and horizontal movement to activation of the drill. With enough time there can be an iteration of the F.I.S.H that has versatile functionality and is capable of assisting in the monitoring of water quality in areas of Latin and South America.

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