STOCKHOLM JUNIOR WATER PRIZE 2025

SOUTH AFRICA:

PROJECT NAME: THE AQUACRUSADER

LEARNERS: Snazo Nzama & Elihle Msomi

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PROJECT SUMMARY

The AquaCrusader is a fully autonomous, AI-powered aquatic robot innovation designed by Snazo Nzama and Elihle Msomi to collect micro plastics (MPs) and nanoplastics (NPs) from streams, rivers, . Operated by a Raspberry Pi and Arduino UNO R4, it uses ultrasonic sensors, GPS mapping, and real-time AI navigation to function without human intervention. Powered by solar panels (effective even underwater) and hydro energy, the Aqua Crusader offers sustainable operation. Its dual-chamber design separates the control system from a highly effective filtration system capable of capturing both MPs and NPs, ensuring minimal disruption to aquatic ecosystems.

Engineered with an eco-friendly, hydrodynamic structure and camouflaged in eco-friendly dark blue paint to blend with its environment, the AquaCrusader is waterproof, insulated, and durable even in harsh aquatic ecosystem conditions. It supports remote control options and emergency manual override, while a gyroscope ensures it remains stable in strong water currents and water pressure. Environmentally conscious and scalable, the AquaCrusader aligns with key South African environmental laws and the United Nations Sustainable Development Goals (SDGs 3, 6, and 13). It exemplifies the 2025 World Environment Day theme, "Solutions to Plastic Pollution," by offering an innovative, intelligent, and eco-conscious solution to one of the planet's most pressing environmental challenges: plastic pollution.

ACRONYMS

- STEM - Science, Technology, Engineering and Mathematics
- MPs - Microplastics
- NPs - Nanoplastics
- rHDP- Recyclable High Density Plastics
- BPA- Bisphenol A
- GPS- Global Positioning System
- AI- Artificial Intelligence
- SDG-Sustainable Development Goals

BIOGRAPHY AND SCHOOL HISTORY

The Project owners are Elihle Msomi and Snazo Nzama. Elihle and Snazo are both 16-year-old Grade 11 learners at Adams College. Elihle is a dedicated and ambitious known for his academic focus and sense of purpose and Snazo is a standout high school learner, known for his excellent academic performance and passion for environmental sustainability.

Adams College was founded in 1853 by the American missionary Dr Newton Adams. It is located in the peri-urban area of Adams Mission within the EThekwini Metropolitan Municipality in the province of KwaZulu-Natal. Adam's College, orginally named Amanzimtoti Institute is one of South Africa's oldest institutions for Africans. Over the years, the school became a pioneering centre of learning, being the first to offer matric and post-matric courses, co-education, and teaching roles to Africans. The school played a significant role in developing leaders such as Albert Luthuli and Z.K. Matthews, and was deeply affected by apartheid-era policies like Bantu Education, Adams College remains committed to academic excellence and character development, upholding values such as responsibility, hard work, and integrity. Its mission is to be a leading, inclusive educational institution, equipping students from all backgrounds with top academic and extracurricular opportunities.

ACKNOWLEDGEMENTS

1. Mr. Zimu, educators, provincial adjudicators and mentors for their supervision and guidance.
2. Our parents Mr. and Mrs Nzama and Mrs and Mrs Msomi for their assistance and support.
3. South African Association for Marine Biological Research (SAAMBR): For allowing us to use their facilities to test our AquaCrusader for adaptability in a marine environment.
4. DIY Electronics, MAKE Electronics, Builders, Amazon and ManTech: Our service providers that supplied us with electrical components.

INTRODUCTION

Microplastics—tiny plastic particles less than 5mm—are a growing threat to water security and hygiene worldwide. They enter freshwater systems through packaging waste, synthetic clothing, personal care products, and industrial runoff, often bypassing traditional water treatment plants. These particles carry toxic chemicals like BPA and phthalates, posing serious health risks such as hormonal disruption and immune system damage, particularly in low-income and rural communities. To combat this, the **AQUACRUSADER** is an autonomous, AI-powered robot designed to detect and remove micro plastics from streams, rivers, dams, and estuaries. Equipped with advanced filtration, GPS navigation, and real-time data reporting, it offers an eco-friendly solution to restore water quality and protect public health. The AQUACRUSADER is a powerful tool to ensure better waste management that is essential in protecting water sources.

BACKGROUND

Plastics have undeniably enhanced our quality of life, serving various practical purposes. However, their widespread use has also had devastating consequences on water sources particularly in the form of microplastics.

Figure 1: Pictures of micro plastics (Source:.www.UNESCOOceanLiteracy.com)

What are microplastics?

The word ‘micro’ refers to something less than the millimeter range but bigger than nanometers. Microplastics are small plastic particles less than 5mm in size, categorized into two types.

- Primary Microplastics are plastic particles manufactured in a small range, like beads, pellets, and nurdles.

- Secondary Microplastics are generated from the degradation of larger plastics.

Despite their minuscule size, their impact on the environment is massive.

Where are microplastics found?

Microplastics have infiltrated every corner of our planet—from the Antarctic ice to the depths of the ocean, the agricultural lands, and even the human body. Research reveals their presence in bottled water, marine organisms, and even the human blood stream and feaces.

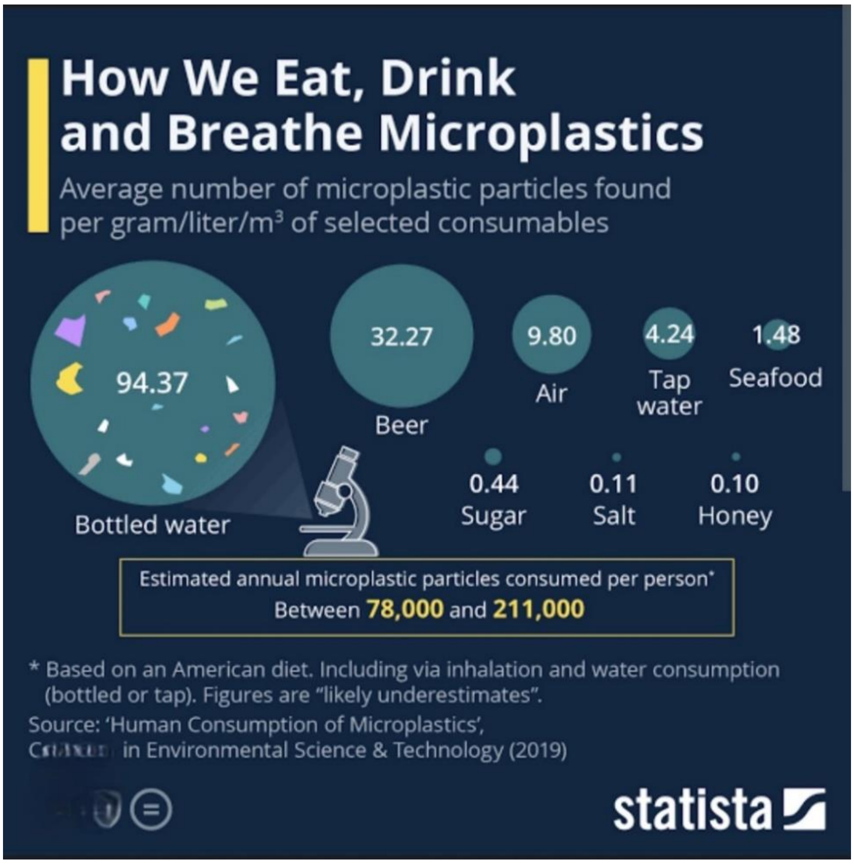

Figure 2: How microplastics enter our bodies?(Source ScienceDirect.com)

How do microplastics enter aquatic environments?

Larger plastic debris breaks down into smaller pieces over time due to weathering and physical processes. Industrial processes can also release microplastics directly into waterways. Everyday items like textiles and personal care products can shed microplastics that enter wastewater systems. Rainfall can also wash microplastics from land into streams, rivers, dams and oceans. Microplastics can be transported throughout the atmosphere and deposited in water bodies.

Figure3: Micro plastic Transport and Degradation Mechanisms (Source: www.epa.gov)

Effects Of Microplastics on

- Humans
  - MPs can trigger inflammation and oxidative stress, which can damage cell DNA, leading to various health problems.
  - MPs can carry carcinogens and mitogens, which can damage DNA, leading to mutations and possibly cancer.
  - They can cause cardiovascular issues like heart attacks and strokes.
- Biosphere MPs can:
  - Impact the soil's biological, chemical, and physical properties.
  - Act as vectors for pollutants.
  - Negatively impact plant growth.
  - Decrease oxygen levels.
- Aquatic Environment
  - Negatively impact on the digestive system, leading to malnutrition, impaired reproduction, and reduced growth.
  - Absorb toxins in the water, which are transferred to organisms that ingest them.
  - Disrupt the delicate environment of aquatic ecosystems.

SOLUTIONS TO MANAGE MICROPLASTICS

Efforts to combat Micro plastics pollution include:

- Ocean cleanup projects and sea-bins
- Coastal cleanups and micro plastic-catching filters
- Biodegradable plastics and plastic-eating enzymes
- Waste-water treatment upgrades and eco-friendly product advocacy
- Machines that collect microplastics in the ocean with human intervention.

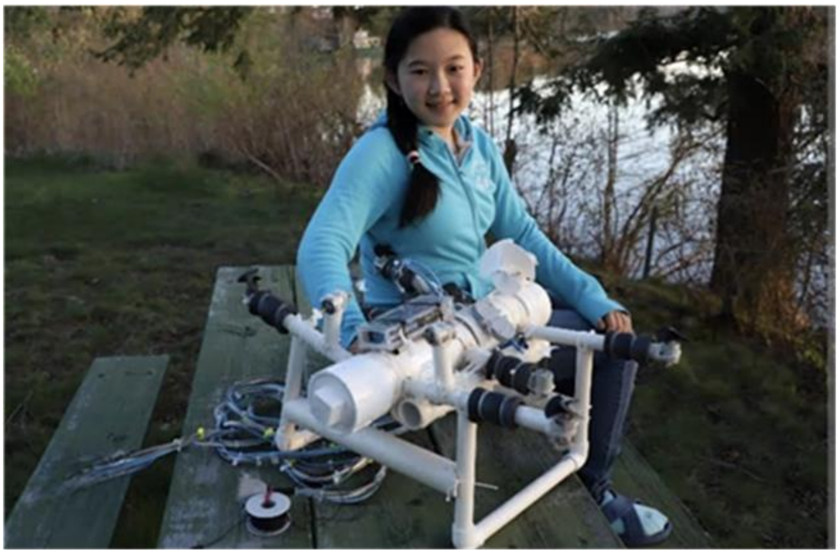

Figure 4: Existing microplastics solution by Anna Du in 2018 (Source.www.researchgate.net)

Figure5: Existing microplastics solutions by Angelo Loh in 2021.(www.horiba.com)

OUR SOLUTION: THE AQUCRUSADER

PROBLEM STATEMENT

Microplastics are polluting freshwater sources, making water unsafe for human consumption and hygiene. They often pass through regular water treatment systems and can harm both the environment and human health. This issue especially affects poor communities that lack access to clean water, raising serious concerns about water safety and public health

HYPOTHESIS:

The AQUACRUSADER minimizes the amount of microplastics in aquatic environments wwithout harming aquatic ecosystems.

AIM:

The aim of this project is to create an innovation that can collect micro plastics in freshwater sources, minimizing the effects they cause in aquatic environments, biosphere and humans.

Figure 6: Aquacrusader Solution

We went through all the design-thinking processes, and our design comprises of the exterior structure and interior structure, which has 2 chambers.

THE EXTERIOR CHAMBER

The robot features a hydrodynamic exterior, coated with eco-friendly dark blue paint, allowing it to glide smoothly through freshwater environments while blending in and minimizing disturbance to aquatic life. It is equipped with an advanced navigation system that uses ultrasonic sensors placed on all sides—front, back, top, bottom, and sides—for detecting and avoiding obstacles and sediment. An AI-powered Raspberry Pi-controlled camera system enables the robot to identify and target microplastics. Propelled by waterproof brush-less motors, the robot moves efficiently underwater, while vertical movement is achieved using 180-degree servo motors that control fin-like structures, inspired by the motion of submarines and stingrays. Solar panels mounted on top provide additional power and are 60% more efficient underwater than in air.

THE INTERIOR CHAMBER

The interior of the robot is divided into two chambers. The upper chambers consist of the control system of the robot. The lower chamber consists of a filtration system that will filter out the MPs and NPs from water source and a propeller that will work along with solar panels to provide electricity to the robot. The control system consists of a Raspberry Pi, which is a hardware platform that is the AI of the robot, which controls the Raspberry Pi camera, allowing the robot to be alternatively controlled by a Bluetooth remote app and our emergency console. All in all, the AI made by a Raspberry Pi enabled us to make the robot AUTONOMOUS by controlling all the robot's functions without it being controlled. The best thing is that the activated AI activates the built-in GPS tracker, so you can view all the movements it makes and design a map of the robot's route. The Raspberry Pi acts as the brain, and it has its companion, the ARDUINO UNO R4, which receives commands from the Raspberry Pi to control the propeller, ultrasonic sensor, and fins since the ARDUINO deals with the movements. The Filtration system utilises sieves of different sizes to trap both MPs and NPs that are 10mm and less in size. This means that the robot can also trap nanoplastics. It has a storage compartment that stores MPs and NPs once they have been absorbed.

SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM)

We used STEM principles throughout the design process.

.Science

- Solar panels were used to convert radiant energy into electrical energy.
- Electric circuits were used as the main power source for our robot. Various laws of Physics were applied.
- The upper fin was installed for fluid dynamic locomotion for the robot, making it more efficient.
- Recyclable density plastics were used to cover the robot, allowing it to be submerged.

Technology

- Ultrasonic sensors were installed to detect any aquatic organisms or any other obstacles in the water source so that the robot can be able to bypass those obstacles.
- A built-in GPS module is used to keep track of the robot's location (AI-based navigation).
- A built-in Bluetooth module is used for control of the robot via a cellphone joystick.
- Artificial Intelligence (AI) was used to aid in programming the robot so that it can be able to perform its various functions.
- We used a Raspberry Pi to code with the Python Language to make the robot's AI.

Engineering

- The robot has an oval-shaped body, allowing it to withstand the water pressure in freshwater systems, so that it can move spontaneously to avoid attacks (hydrodynamic).

- Engineering was used in the actual construction of the physical components of the robot by applying different Engineering Laws.
- A gyroscope was used to help ensure that the robot stays in place, preventing it from tilting due to ocean currents.

Mathematics

- It was used to calculate the size of our robot for maximum efficiency and to prevent buoyancy.
- After calculations, the total cost of the prototype is R8493-69
- The collection capacity of the robot is a 0,83kg/h 4kg per load in 4,8 hours meaning it can collect approximately 5 loads in 24hrs.
- the speed of the robot was calculated as follows:

21'16"/km (21 minutes and 16 seconds per kilometer) into speed, you can calculate how many kilometers are covered in one hour.

Step 1: Convert the pace to seconds

21 minutes 16 seconds =
21×60+16=127621 \times 60 + 16 = 1276 seconds per kilometer

Step 2: Calculate how many kilometers in an hour

There are 3600 seconds in one hour:

Speed=3600 seconds/hour1276 seconds/km≈2.82 km/h\text {Speed} = \frac{3600 \text{ seconds/hour}}{1276 \text{ seconds/km}} \approx 2.82 \text{ km/h}Speed=1276 seconds/km3600 seconds/hour≈2.82 km/h

Final Answer:2.82 km/h **is the speed for a pace of** 21'16"/km**.**

ADVANTAGES AND DISADVANTAGES

As with everything in the world, robots have advantages and disadvantages.

Advantages	Disadvantages
Increased Efficiency: Continuous operation at night and during the day, which maximizes the collection capacity.	Maintenance difficulty: Underwater maintenance and repairs can be costly and complex. Requires minimal maintenance and repairs since it is an autonomous, wireless dive-in, hop-off robot.

Real-time monitoring: Integrated sensors can track MPs concentration and the robot's performance.	High Development Costs: Advanced technologies and materials can be expensive, especially since it is advisable to use tested, high-quality materials such as those approved by the SABS (South African Bureau of Standards).
Scalability & Adaptability: Modular design suits diverse aquatic environments.	Weather Constraints: Surface weather conditions can impact the robot's operations, e.g. heavy rainfall and storm events which is why we use gyroscopic stabilization ensuring operation in adverse weather conditions.
Solar Power Limitation and sustainability: It does not rely only on solar power, but it also relies on hydropower. Powered by renewable energy, reducing dependency on external power sources.	

SAFETY AND WORK EFFICIENCY

The robot is insulated with silicon and foam, allowing it to be waterproof. Due to the insulation, the robot can function, even during lower temperatures. The wires are double insulated to ensure that charges can move fast even in very low temperatures.

ECO-FRIENDLINESS

The robot utilizes renewable energy produced by solar panels and the hydroelectric power system and operates without harming aquatic life or disturbing aquatic ecosystems.

The micro plastics collected by the robot can be used in two ways:

1. The collected MPs can be converted into trash cans that will be placed at the shore.
2. They can be used in the production of biodegradable plastics.

This can happen if we partner with recycling companies and the local municipality.

This robot contributes to safeguarding aquatic ecosystems by targeting and removing microplastics, a growing threat to aquatic biodiversity and food chains.

ALLIGNMENT TO THE SUSTAINABLE DEVELOPMENT GOALS (SDGs)

SDG3: GOOD HEALTH AND WELL-BEING

The **AquaCrusader** aligns with **SDG 3: Good Health and Well-being** by reducing microplastics and toxic chemicals like BPA in water, which helps protect human health. By improving water quality and food safety, it lowers the risk of disease linked to polluted aquatic environments and supports healthier ecosystems and communities.

SDG6: CLEAN WATER AND SANITATION

The **AquaCrusader** supports **SDG 6: Clean Water and Sanitation** by removing microplastics and nanoplastics from water bodies, helping to improve water quality and reduce pollution. Its autonomous, eco-friendly design promotes sustainable water management and protects aquatic ecosystems, contributing to safe, clean water for people and the planet.

SDG13: CLIMATE ACTION

The **AquaCrusader** supports **SDG 13: Climate Action** by protecting aquatic ecosystems that act as vital carbon sinks and removing plastic pollution that harms biodiversity and climate resilience. Powered by renewable solar and hydro energy, it reduces greenhouse gas emissions and promotes sustainable water management to help mitigate and adapt to climate change.

ALIGNMENT WITH SOUTH AFRICAN LEGISLATION

National Water Act no.36 of 1998

The AquaCrusader is an advanced aquatic robot engineered to collect microplastics from oceans, estuaries, rivers, and freshwater systems. Our innovation directly supports the goals of The National Water Act (Act No. 36 of 1998) by enhancing sustainable water resource protection and pollution prevention.

Key Features of the AquaCrusader

FEATURE	ALLIGNMENT TO NATIONAL WATER ACT
Ultrasonic Sensors	Detect obstacles and aquatic organisms in real time, ensuring safe navigation and minimizing disruption to aquatic life, in line with Section 2 of the Act – protection of aquatic ecosystems

Raspberry Pi-Controlled Camera System	Identifies and targets microplastics with precision in freshwater environments. This supports data-driven monitoring, aligning with Section 24 – National Monitoring Systems
Underwater Solar Panels	Powered by renewable solar energy, the AquaCrusader reduces environmental footprint while operating sustainably – in the spirit of the Act's emphasis on responsible resource use

Water Services Act no. 108 of 1997

The AquaCrusader supports the goals of South Africa's Water Services Act (No. 108 of 1997), which aims to provide safe, clean, and sustainable water for all while protecting the environment.

- Improving Water Quality:
  The AquaCrusader removes harmful microplastics (MPs) and nanoplastics (NPs) from freshwater systems, directly contributing to the Act's objective of maintaining high water quality for both human use and ecological balance.
- Pollution Prevention:
  Aligned with the Water Services Act's emphasis on pollution control, the AquaCrusader actively prevents water contamination by filtering plastics before they can degrade and cause long-term damage to aquatic ecosystems.
- Sustainable Water Management:
  The AquaCrusader runs on solar panels, providing a renewable energy source that supports the sustainable use of water resources. This aligns with the Act's goal to promote environmentally responsible practices in managing water.
- Ensuring Access to Clean Water:

By removing contaminants, the AquaCrusader helps protect water sources, contributing to safe access to clean water, which is at the core of the Water Services Act.

National Environmental Management Act no, 107 of 1998

The AquaCrusader is an innovative autonomous robot designed to combat the growing threat of microplastics (MPs) and nanoplastics (NPs) in our oceans, rivers, estuaries, and freshwater bodies. This technology directly supports the objectives of South Africa's National Environmental Management Act (NEMA) (Act No. 107 of 1998), which sets the framework for sustainable environmental management and pollution prevention.

The AquaCrusader aligns with **World Environment Day 2025's theme, "Solutions to Plastic Pollution,"** by offering an innovative approach to combat plastic waste in water bodies.

- **Targeting Microplastics**: Using advanced filtration systems, the AquaCrusader removes microplastics (MPs) and nanoplastics (NPs) from oceans, rivers, and estuaries, tackling one of the most critical forms of water pollution.
- **Reducing Plastic Pollution**: By capturing plastics before they break down, it helps mitigate the harmful effects of plastic on marine and freshwater ecosystems.
- **Promoting Sustainable Practices**: Powered by solar energy, the AquaCrusader reduces dependence on fossil fuels, supporting sustainable environmental practices.

Stockholm Junior Water Prize 2025 theme: WATER FOR CLIMATE ACTION

The AquaCrusader aligns strongly with the 2025 Stockholm Junior Water Prize theme, **"Water for Climate Action,"** by offering a practical, technology-driven solution that addresses the climate impacts of plastic pollution in aquatic environments. Microplastics and nanoplastics disrupt ecosystems by degrading under sunlight which will release greenhouse gases like methane and ethylene. In water bodies, MPS can interfere with plankton that absorb carbon dioxide, potentially weakening one of the planet's most important carbon sinks. By removing these pollutants, the AquaCrusader helps restore biodiversity and the natural capacity of water bodies to support climate resilience. Powered by solar and hydroelectric energy, it operates with zero emissions, demonstrating how clean energy can be integrated into water management technologies. Its real-time AI navigation and autonomous monitoring improve the efficiency of pollution control, while its filtration system ensures that aquatic life remains undisturbed. The robot also promotes climate adaptation by protecting water resources and supporting sustainable ecosystems in the face of increasing environmental stress.

COMPARISON OF EXISTING MODELS AND THE AQUA CRUSADERS

Below is a comparison between the Aqua Crusader's unique features and how it stands out from existing microplastic (MP)-collecting robots:

EXISTING MODELS	AQUACRUSADER
Autonomous Operation	
Many require human operation or intervention for navigation, limiting their efficiency in large-scale or remote environments	Fully autonomous with Raspberry Pi and Arduino UNO R4 for control. It can navigate, detect obstacles, and collect microplastics without human intervention

Advanced Sensing and Navigation	
Typically have fewer sensors and might not be as adaptable to different water conditions or capable of avoiding marine life effectively	Equipped with ultrasonic sensors on all sides (front, back, top, bottom, sides), it can detect obstacles, avoid aquatic organisms, and safely navigate various water bodies, ensuring minimal environmental disruption.
Solar-Powered System:	
Many rely on limited battery power or external energy sources, reducing their operational time and increasing the need for human involvement	Uses solar panels that work up to 60% underwater, providing continuous, renewable energy to the robot, ensuring it can operate autonomously for long periods without needing frequent recharging.
Filtration System	
Often have less advanced filtration systems that may not be as effective in capturing both large and small plastic particles	Features a unique dual-chamber design: an upper control chamber and a lower filtration chamber with sieves for effective microplastic collection, capable of filtering both MPs and NPs.
Durability and Camouflage	
Some have visible designs that can attract attention and may not be as resistant to environmental challenges like extreme temperatures or saltwater corrosion.	Painted dark blue for camouflage, allowing it to blend into water environments while operating in various aquatic conditions. It's also waterproof, insulated, and built for durability in harsh environments
Aquatic Animal Repellent	
Lack such specific features for preventing interactions with aquatic animals	Equipped with aquatic animal repellent, ensuring safe operation in marine environments without attracting predators
GPS Mapping and Real-Time Navigation	

Many lack GPS mapping, limiting their ability to cover larger areas or operate in challenging conditions without human oversight	Includes a GPS tracker that allows the robot to create detailed maps of its operating area, ensuring more efficient microplastic collection over large or hard-to-reach areas

MATERIALS AND METHODS

SABS approved products were used such as:

- Galvanized metal frame
- Recyclable high density plastic

	Underwater Thrusters
	Waterproof ultrasonic sensor plugs
	Raspberry PI Kit
	Servo motor

	Bread board
	Silicon Glue

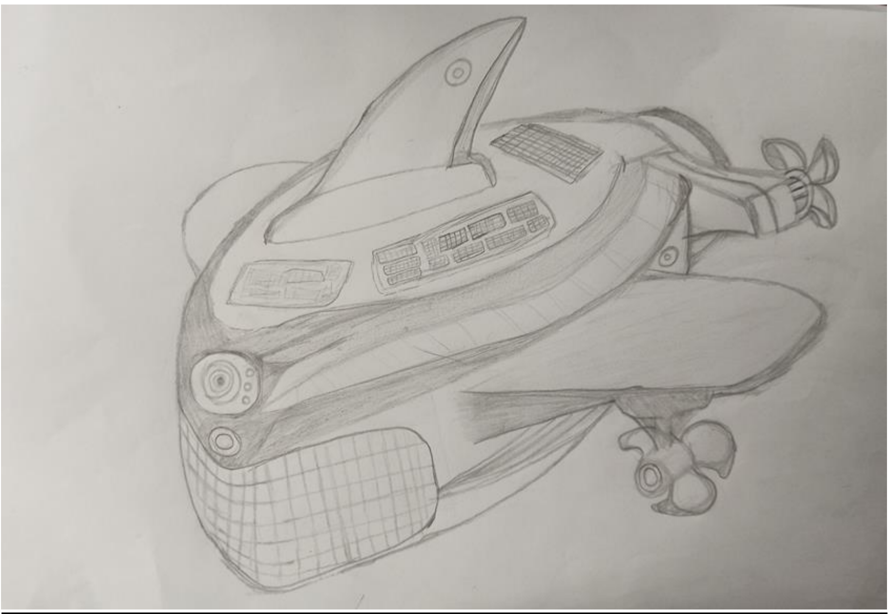

Figure 7: Sketch of the AQUACRUSADER

COST IMPLICATIONS

Materials used	Cost (Rands)	The estimated cost for Real Model (Rands)	Shops to buy
Raspberry Pi 5 Kit	4899	4899	DIY
Arduino starter kit	469	469	AMAZON
Servo Motor	86	86	DIY
Underwater Thrusters	1995	3285	MAKE
Ultrasonis Sensors	125,27	248,39	DIY

Silicone Glue	169,98	424,95	BUILDERS
Galvanised Metal Frame	749,44	1163,39	ManTech
Total	**8493,69**	**10756,03**	

CONCLUSION

The AquaCrusader represents a major leap forward in microplastic collection technology with its autonomous operation, advanced sensor system, solar-powered efficiency, and environmentally friendly design. By combining cutting-edge features and sustainability, it offers a more effective and adaptable solution compared to current robots in the field, ensuring a cleaner, healthier aquatic environment.

With its ability to function in aquatic environments and its eco-friendly features, our AI-powered robot stands as the most viable and forward-thinking solution to combat microplastic pollution. This project aligns with 2030 STEM goals, paving the way for a cleaner and more sustainable future.

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