# Development of a Remote-Controlled Boat for Water Source Cleaning through 3D Printing

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***Abstract*— This project addresses water pollution by developing a Remote-Controlled Aquatic Boat. Utilizing 3D printing technology, the prototype aims to provide an automated solution for efficient removal of surface debris in aquatic environments.**

**Keywords—3D Printing, Ocean, Plastic, Cleaning.**

## I. Introduction

The increasing pollution of water sources represents a significant environmental challenge worldwide. In response to this issue, this report details the development of a Remote Water Source Cleaning Boat using 3D printing technology.

This project seeks to address the critical need to combat surface contamination in aquatic environments by presenting an innovative and automated solution for efficient debris removal. The following paper outlines the conceptual design, detailed planning, construction with 3D printing technology, and prototype evaluation.

## II. Problem Description

Water pollution is a serious global threat that affects the health and well-being of millions of people and ecosystems [1]. The increasing pollution of water sources represents a significant environmental challenge that can have adverse impacts on aquatic life, biodiversity, human health, and socio-economic development worldwide [2]. More specifically, the rise in surface-level debris and waste materials poses a significant threat to the delicate balance of marine environments, necessitating immediate and effective intervention.

One of the challenges in addressing water pollution is the difficulty of accessing and cleaning remote or hard-to-reach water sources, such as rivers, lakes, ponds, and coastal areas. Conventional methods of water treatment, such as filtration, coagulation, chlorination, and ozonation, may not be feasible or effective in these situations. Moreover, these methods may generate secondary pollutants or require high energy and maintenance costs. Therefore, there is a need for innovative and sustainable solutions that can provide efficient and low-cost water cleaning services in remote areas.

## III. Objectives

### A. General Objective

The primary aim of this project is to develop an open-source, 3D-printed remote-controlled aquatic vehicle focused on the cleaning of water environments.

### B. Specific Objectives

- Evaluate the durability of the materials used in the 3D-printed prototype under prolonged exposure to water, considering factors such as material degradation, resistance to marine conditions, and long-term sustainability.
- Develop and implement sustainable technologies for the conservation and responsible utilization of oceans, seas, and marine resources, aiming to preserve marine biodiversity, reduce pollution, and ensure the long-term health and productivity of aquatic ecosystems.
- Ensure the prototype's design is user-friendly, allowing for easy maintenance, accessibility for potential upgrades, and simplicity in operation for individuals engaging with the technology.
- Encourage community involvement, garner feedback, and promote further innovation by making project documentation, designs, and findings accessible to a wider audience, fostering collaborative improvements.

## IV. Justification

This project stands as a response to the critical need for innovative solutions to combat marine pollution and preserve the vitality of life below water. The goal of this project is to create an innovative solution that can effectively clean water sources and mitigate pollution.

The boat is designed to be modular, customizable, and scalable, using 3D printing technology to create different components and configurations according to the specific needs and conditions of each water source and water cleaning operations.

This project not only addresses the immediate challenges of marine pollution but also lays the foundation for scalable, sustainable practices essential for the conservation and responsible utilization of our oceans and marine resources, aligning with the objectives of Sustainable Development Goal 14 [3].

## V. Conceptual Design

The foundation of the 3D model project is rooted in the innovative design of a Catamaran boat featuring a highly efficient waste-collecting mesh.

The following figures show the boat model without the mesh:

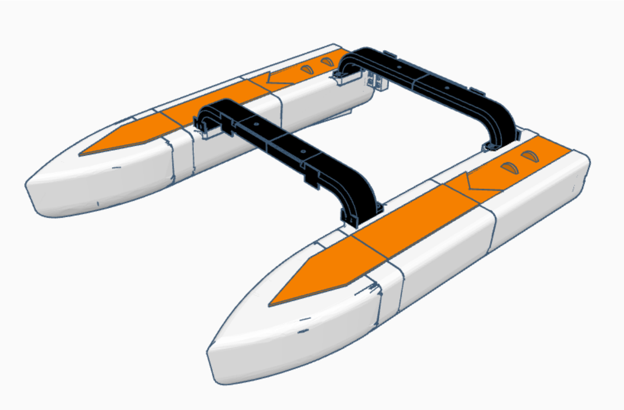


*Fig. 1. Model 3D (Front). Original work.*

The model was replicated using Tinkercad.

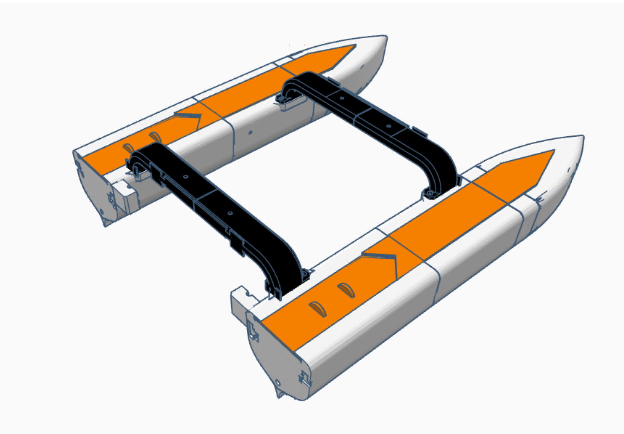


*Fig. 2. Model 3D (Back). Original work.*

The selected printing technique for realizing this project is FDM (Fused Deposition Modeling), a choice made based on its compelling advantages in the market:

1. **Widespread Applicability:** FDM stands out for its versatility, making it applicable to a broad spectrum of projects and ensuring adaptability to various design complexities.
2. **Lower Construction Costs:** Embracing FDM translates to a more cost-effective production process, aligning with economic considerations without compromising on the quality of the final product.
3. **Extensive Range of Materials:** FDM offers a diverse selection of materials, each with distinct levels of strength and durability. This diversity allows for the tailoring of material choices to meet specific project requirements, enhancing the overall robustness of the final prototype.

Regarding the printing material, careful attention is paid to the prototype's prolonged exposure to sunlight. This factor makes the resistance to temperature deformation a crucial consideration. Therefore, the chosen material for printing is ***ASA***, which is strategically selected not only for its excellent temperature-resistant properties but also for its cost-effectiveness.

This material selection ensures the prototype's durability and longevity, meeting the project's demands in an optimal and economically efficient way. All these features can be seen in the following figure:

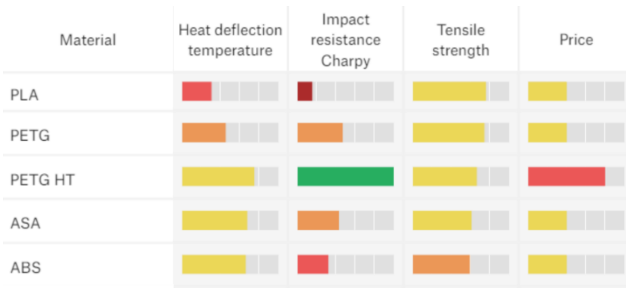



*Fig. 3. FDM materials' comparison. Source: [4]*

## VI. Planning

### A. Schedule

The project has an estimated duration of **2 months**, divided by **main activities** that will be divided by **week**. Each activity has a specific objective and a time assigned for its realization. The schedule is presented in the following table:

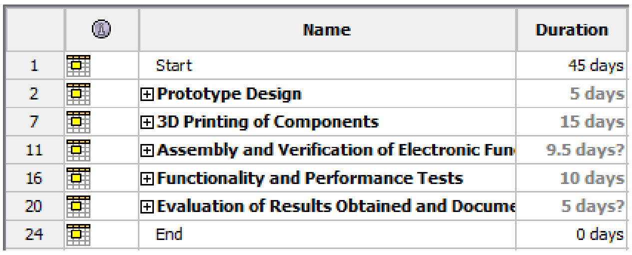
TABLE I
WEEKLY SCHEDULE

<table>
<tr><th>Week</th><th>Activity</th><th>Objective</th></tr>
<tr><td>1</td><td>Prototype Design</td><td>Define the technical and aesthetic characteristics of the remote cleaning boat.</td></tr>
<tr><td>2</td><td rowspan="3">3D Printing of Components</td><td rowspan="3">Print the necessary parts for the assembly of the prototype, using a 3D printer.</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td rowspan="2">Assembly and Verification of Electronic Functioning</td><td rowspan="2">Join the printed parts and connect the electronic components, such as motors, batteries, and ESC. Verify that the prototype works correctly and can be controlled remotely.</td></tr>
<tr><td>6</td></tr>
</table>

| | | |
|---|---|---|
| 7 | Functionality and Performance Tests | Perform tests in different water conditions, such as level, turbulence, pollution and temperature. Evaluate the cleaning capacity, efficiency, speed and resistance of the prototype |
| 8 | | |
| 9 | Evaluation of Results Obtained and Documentation | Analyze the data collected in the tests and compare them with the objectives set. Write the final documentation of the project, including the findings, conclusions and recommendations. |

The overall schedule for the project, generated using the ProjectLibre software, is shown below.

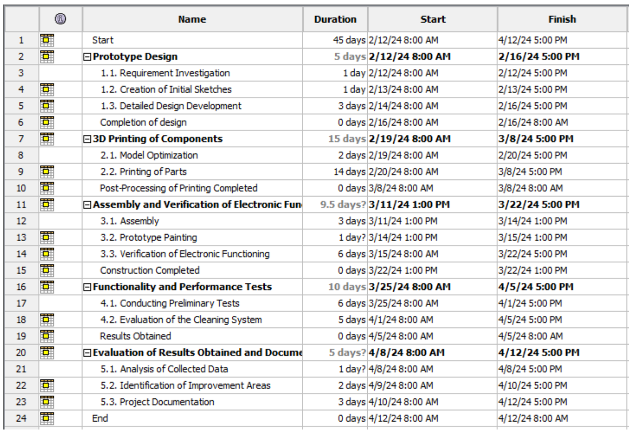
This systematic approach facilitates effective planning and real-time monitoring of project advancement, with the primary activities outlined over weeks and their respective durations specified in days.



| | | Name | Duration |
|---|---|---|---|
| 1 | | Start | 45 days |
| 2 | | ⊞Prototype Design | 5 days |
| 7 | | ⊞3D Printing of Components | 15 days |
| 11 | | ⊞Assembly and Verification of Electronic Fun | 9.5 days? |
| 16 | | ⊞Functionality and Performance Tests | 10 days |
| 20 | | ⊞Evaluation of Results Obtained and Docume | 5 days? |
| 24 | | End | 0 days |

*Fig. 4. General schedule. Original work.*

The subsequent figure provides an in-depth breakdown of the main activities into secondary tasks, offering a more granular perspective on specific responsibilities within each phase of the project.



| | | Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | | Start | 45 days | 2/12/24 8:00 AM | 4/12/24 5:00 PM |
| 2 | | ⊟Prototype Design | 5 days | 2/12/24 8:00 AM | 2/16/24 5:00 PM |
| 3 | | 1.1. Requirement Investigation | 1 day | 2/12/24 8:00 AM | 2/12/24 5:00 PM |
| 4 | | 1.2. Creation of Initial Sketches | 1 day | 2/13/24 8:00 AM | 2/13/24 5:00 PM |
| 5 | | 1.3. Detailed Design Development | 3 days | 2/14/24 8:00 AM | 2/16/24 5:00 PM |
| 6 | | Completion of design | 0 days | 2/16/24 8:00 AM | 2/16/24 8:00 AM |
| 7 | | ⊟3D Printing of Components | 15 days | 2/19/24 8:00 AM | 3/8/24 5:00 PM |
| 8 | | 2.1. Model Optimization | 2 days | 2/19/24 8:00 AM | 2/20/24 5:00 PM |
| 9 | | 2.2. Printing of Parts | 14 days | 2/20/24 8:00 AM | 3/8/24 5:00 PM |
| 10 | | Post-Processing of Printing Completed | 0 days | 3/8/24 8:00 AM | 3/8/24 8:00 AM |
| 11 | | ⊟Assembly and Verification of Electronic Fun | 9.5 days? | 3/11/24 1:00 PM | 3/22/24 5:00 PM |
| 12 | | 3.1. Assembly | 3 days | 3/11/24 1:00 PM | 3/14/24 1:00 PM |
| 13 | | 3.2. Prototype Painting | 1 day? | 3/14/24 1:00 PM | 3/15/24 1:00 PM |
| 14 | | 3.3. Verification of Electronic Functioning | 6 days | 3/15/24 8:00 AM | 3/22/24 5:00 PM |
| 15 | | Construction Completed | 0 days | 3/22/24 1:00 PM | 3/22/24 1:00 PM |
| 16 | | ⊟Functionality and Performance Tests | 10 days | 3/25/24 8:00 AM | 4/5/24 5:00 PM |
| 17 | | 4.1. Conducting Preliminary Tests | 6 days | 3/25/24 8:00 AM | 4/1/24 5:00 PM |
| 18 | | 4.2. Evaluation of the Cleaning System | 5 days | 4/1/24 8:00 AM | 4/5/24 5:00 PM |
| 19 | | Results Obtained | 0 days | 4/5/24 8:00 AM | 4/5/24 8:00 AM |
| 20 | | ⊟Evaluation of Results Obtained and Docume | 5 days? | 4/8/24 8:00 AM | 4/12/24 5:00 PM |
| 21 | | 5.1. Analysis of Collected Data | 1 day? | 4/8/24 8:00 AM | 4/8/24 5:00 PM |
| 22 | | 5.2. Identification of Improvement Areas | 2 days | 4/9/24 8:00 AM | 4/10/24 5:00 PM |
| 23 | | 5.3. Project Documentation | 3 days | 4/10/24 8:00 AM | 4/12/24 5:00 PM |
| 24 | | End | 0 days | 4/12/24 8:00 AM | 4/12/24 8:00 AM |

*Fig. 5. Work Breakdown Structure. Original work.*

To improve the visualization and continuous monitoring of the project, a Gantt chart is introduced.

This graphical representation illustrates the chronological interrelationship between major and minor activities, along with key project milestones.

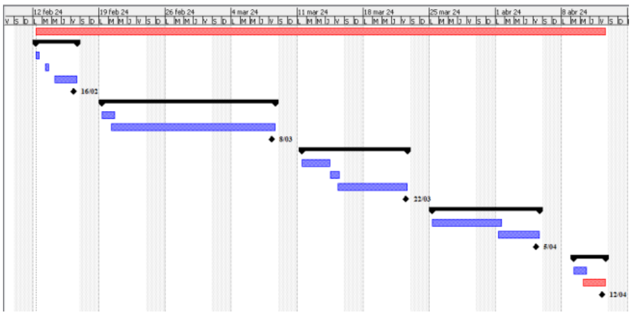


*Fig. 6. Gantt Chart. Original work.*

**Key milestones** in the project (seen in the Gant Chart as rhomboidal black figures) denoting critical junctures or notable accomplishments, are articulated below:

- Completion of design.
- Post-Processing of Printing Completed.
- Construction Completed.
- Results Obtained.

## VII. Construction

In this phase, crucial optimizations are applied using the PrusaSlicer software to the key components of the 3D model before initiating the printing process. This involves refining the body parts of the boat and the connections between the boat bodies.

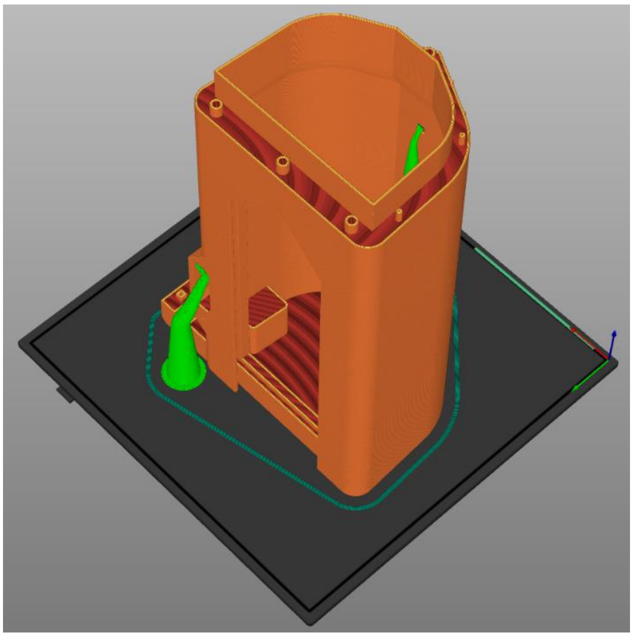


*Fig. 7. Electronics Compartment (Body). Original work.*

The justification for specific parameters, such as the layer height and the use of organic supports is outlined below.

It’s important to keep in mind that the optimization was made for printing the model in an Artillery Hornet printer.

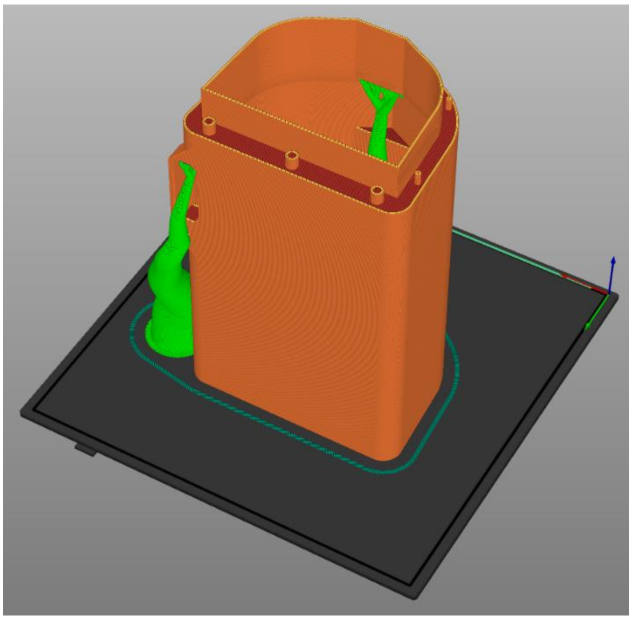


*Fig. 8. Middle Body. Original work.*

The selected parameters, including a layer height of 0.25, are strategically chosen to balance printing speed and detail accuracy:

According to the Maker Hacks review, the Artillery Hornet 3D printer has a nozzle diameter of 0.4 mm [5], which means that a layer height of 0.25 is within the recommended range of 0.2 to 0.3 times the nozzle diameter.

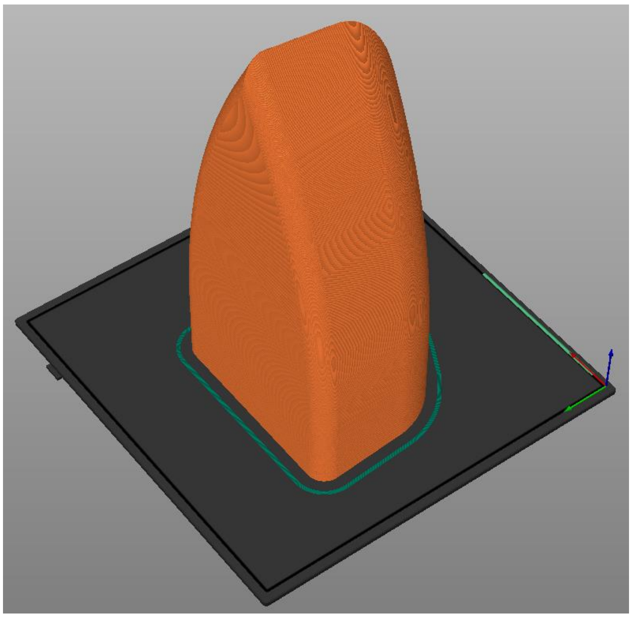


*Fig. 9. Frontal Body. Original work.*

This optimization ensures the efficient production of the boat's body and its structural connections, contributing to the overall functionality of the prototype.

Additionally, the use of organic supports helps to minimize material consumption and waste, as well as to reduce the post-processing time and effort.

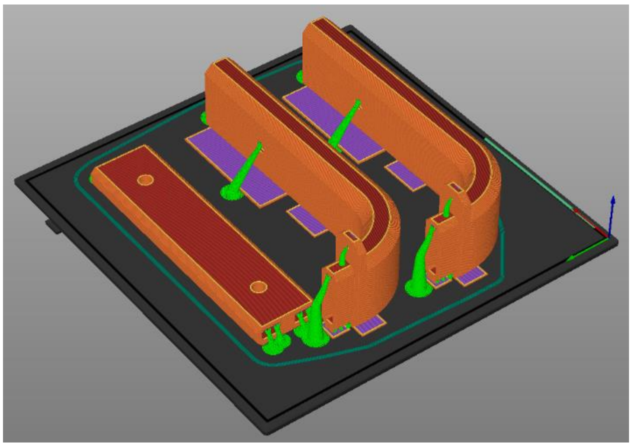


*Fig. 10. Linking Parts. Original work.*

The tangible realization of the 3D model is evident in the physical prototype. Notably, the prototype includes all its components and features a waste-collecting mesh at the rear of the boat, emphasizing its purpose in efficient debris removal.

*Fig. 11. Real Prototype with Mesh. Original work.*

An alternate perspective of the prototype is presented, showcasing its details alongside the remote control. This visual provides a comprehensive view of the boat's design and its user interface.

*Fig. 12. Real Prototype with Remote Control. The photos of the prototype were taken from [6]*

## VIII. Evaluation and Conclusions

### A. *Possible improvements*

#### 1) *Waterproof Coating or Paint*

The proposed enhancement encompasses the application of a specialized waterproof coating or paint to the surface of the cleaning boat. This protective layer functions as a robust barrier, shielding the boat's structural components from prolonged water exposure, thereby mitigating potential degradation and corrosion.

By fortifying the boat against environmental elements, this treatment significantly prolongs its operational lifespan, ensuring sustained efficacy in cleaning activities within diverse aquatic environments.

*Fig. 13. 3D Print on Water. Source: [7]*

#### 2) *Mesh Location*

Strategically relocating the mesh assembly to the boat's frontal section represents a substantial enhancement in design. This pivotal adjustment aims to minimize potential collisions between incoming debris and the vehicle, optimizing the efficiency of waste retrieval operations. It also ensures smoother passage of debris into the collection mechanism, augmenting the overall effectiveness of the cleaning boat in gathering surface-level waste across aquatic environments.

#### 3) *Collection System Optimization*

The proposal aims to augment the prototype's waste collection efficiency by implementing a frontal debris channeling apparatus. This feature, akin to the mechanism employed in Ocean Clean-Up's Interceptor 007 [8], is designed to amplify the vehicle's effective collection area while directing floating debris towards the collection mesh.

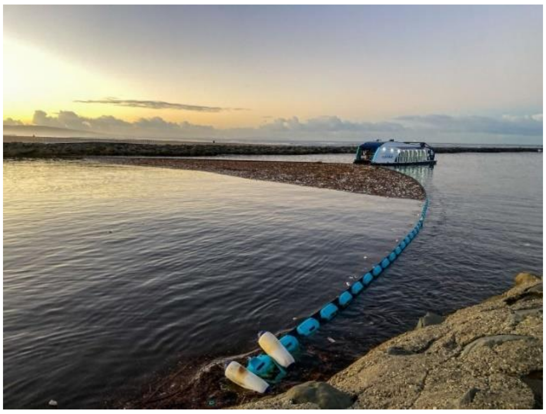


*Fig. 14. Interceptor 007 Structure. Source: [9]*

The instrument will be positioned at the forefront of the aquatic vehicle, functioning as an extended funnel-like structure. Its purpose is to optimize the capture of surface-level waste and streamline its movement towards the onboard collection mesh, thereby augmenting the vehicle's waste retrieval capacity.

#### 4) *Change propeller location*

To avoid potential disruptions within the operational water sources, a more favorable approach involves the adoption of an external turbine configuration situated above the water surface. This proposed modification seeks to eliminate disturbances in aquatic ecosystems while ensuring the seamless functionality of the prototype.

By relocating the turbine to an external position, it minimizes direct contact with water bodies, mitigating any potential environmental impact and optimizing the operational efficiency of the prototype in diverse aquatic environments.

*Fig. 15. Alternative Turbine Configuration. Source: [10]*

### B. *Future jobs*

The project’s advancements open up new possibilities for future applications, improving both efficiency and environmental sustainability. Some of the future jobs that could benefit from this project are:

#### 1) *Autonomous Pilot with Pre-established Route:*

The incorporation of an autonomous pilot with a pre-established route holds the potential to eliminate the human factor in the proper functioning of the cleaning boat. This development not only enhances operational precision but also ensures a consistent and reliable performance, particularly crucial in challenging aquatic environments.

#### 2) *Reutilization of Collected Plastic:*

A pivotal aspect of future jobs involves the thoughtful reuse of the collected plastic. The aim is to categorize plastic waste and utilize it in producing new filaments, which can, in turn, be employed to fabricate additional prototypes.

This circular approach not only contributes to environmental sustainability but also aligns with the principles of recycling and resource efficiency.

*Fig. 16. Recycling 3D filament. Source: [11]*

*3) Water Quality Reading with Sensors:*

The integration of sensors for water quality readings represents a significant leap forward. This feature is designed to gather valuable data for future investigations, aiding in the continuous monitoring and assessment of water conditions. The insights gained can inform decision-making processes and contribute to a deeper understanding of environmental dynamics.

*4) Photovoltaic System:*

In a commitment to eco-friendly practices, a future job involves transitioning to a system powered by solar panels. This transition aims to eliminate the use of batteries, which pose environmental hazards. Harnessing the energy of the sun not only reduces the ecological footprint but also aligns with sustainable energy practices, enhancing the overall environmental impact of the water cleaning system.

*Fig. 17. Implementation of photovoltaic system. Source: [12]*

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