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Towards Accessible Aquatic Cleanup: A Low-Cost Solution for Floating Waste Extraction

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ABSTRACT

Advancements in environmental technologies provide promising solutions for mitigating surface water pollution. This research introduces a low-cost, autonomous floating water waste extractor designed to efficiently remove lightweight pollutants such as microplastics and small debris. The system utilizes a conveyor mechanism driven by DC motors to effectively capture floating waste and transfer it to a secure compartment for disposal. Made from widely available and cost-effective materials, the extractor is an affordable and scalable solution, making it particularly suitable for deployment in resource-constrained areas. Rigorous testing has demonstrated high efficiency in capturing debris weighing under 3 grams, although performance gradually declines as debris weight increases. Its lightweight design ensures smooth operation in various aquatic environments, while its modular construction allows for easy scalability and maintenance. The system's adaptability enables customization for different pollution levels and its deployment in lakes, rivers, and urban waterways. The autonomous operation minimizes the need for human intervention, reducing labor costs and enhancing efficiency in large-scale water cleanup initiatives. These results highlight the extractor's potential to improve water pollution management by offering an automated, sustainable, and accessible solution. This innovation contributes to the preservation of water quality by reducing surface contaminants, benefiting both ecological health and human populations reliant on clean water sources. Future work will focus on optimizing the system's efficiency for handling heavier waste, integrating smart monitoring features such as real-time pollutant detection and AI-based waste classification, and enhancing energy efficiency through solar-powered operation. This proposed system represents progress in sustainable water management, providing a practical and adaptable approach to mitigating aquatic pollution in diverse environmental conditions.

Keywords: Waste Extraction, Water, Floating, Microplastics, Low cost.

1. Introduction

In a world where environmental challenges are intensifying, water pollution has emerged as a pressing issue with profound implications for ecosystems, public health, and economies. Bangladesh, a nation heavily reliant on its rivers and water bodies, faces a particularly severe pollution crisis, as plastic waste, industrial effluents, and other debris accumulate on water surfaces, threatening both marine biodiversity and human communities [1]. Traditional cleanup methods, although beneficial, are often labor-intensive, costly, and lack the efficiency to address the scale of contamination present in such environments [2]. As a result, there is a growing need for innovative, low-cost technologies that can operate autonomously and effectively in diverse water conditions. Recent advancements in autonomous, cost-effective devices have opened new avenues for tackling environmental challenges. This research presents a novel solution: a floating water waste extractor, engineered to collect surface-level pollutants from water bodies efficiently [3]. Designed with affordability and accessibility in mind, this extractor leverages readily available components, including DC motors, a conveyor belt, and a propeller system, to ensure smooth navigation and effective waste collection. Initial testing highlights the device's capability to achieve a 100% success rate in capturing lightweight debris up to 3 grams, though performance declines as the waste load increases, indicating a need for further refinement.

This research explores the development of a low-cost floating water waste extractor designed to address surface pollution in water bodies. The extractor utilizes readily available components, including DC motors, a conveyor belt, batteries, and a propeller system, to create an efficient and accessible solution for collecting floating debris. By prioritizing affordability and simplicity, this project aims to make waste management technology accessible to resource-limited regions, particularly in developing countries like Bangladesh, where traditional pollution control infrastructure may be inadequate or unavailable. Through this approach, the study seeks to empower communities with a practical tool for environmental protection, contributing to cleaner waterways and improved public health.

2. Literature Review

In the field of water pollution control, extensive research has been conducted to develop effective and affordable technologies for removing waste from water bodies, establishing a strong foundation for further innovation. Various studies have explored the use of low-cost, autonomous systems to tackle surface water pollution [4].

One notable research effort introduced a floating boom system designed to trap floating debris in rivers, allowing for easy collection and disposal, thereby reducing pollution levels [5]. This solution highlights the importance of affordability and simplicity in developing pollution control technologies for large-scale implementation in developing regions. Further advancements have led to the integration of automated mechanisms within water-cleaning devices [6]. For instance, a recent study proposed the use of conveyor belt systems powered by DC motors to improve the efficiency of waste collection on water surfaces. The device was designed to capture lightweight pollutants such as plastic bottles and Styrofoam, providing a practical approach to surface-level cleanup in lakes and ponds [7]. While these systems offer valuable assistance in waste collection, they often struggle with larger debris and may lack adaptability to varying water conditions. The incorporation of real-time navigation and remote-control capabilities has also been explored to enhance the functionality of waste collection devices in dynamic environments [8]. One study implemented GPS-based navigation in floating waste collectors, allowing them to autonomously target high-pollution areas within larger water bodies. This approach emphasizes the importance of precision and flexibility, which are critical for addressing pollution hotspots effectively [9]. Additionally, the use of sustainable and recyclable materials in water pollution devices has been highlighted as a key area of innovation, particularly in reducing the environmental impact of the devices themselves. Despite these advancements, there remains a gap in the development of affordable, accessible solutions that utilize commonly available components and do not require complex manufacturing processes [10]. A recent study addressed this gap by introducing a low-cost floating waste collector built with readily available materials such as DC motors, conveyor belts, and plastic enclosures. This design not only reduces production costs but also simplifies maintenance, making the device more accessible for widespread use in resource-constrained regions [11][12]. The research underscores the pressing need for continued exploration of cost-effective and scalable solutions that utilize accessible technologies to address water pollution. This body of work highlights the ongoing efforts to develop water waste extraction technologies that are both efficient and affordable, paving the way for further innovations in environmental sustainability. These advancements not only contribute to cleaner water bodies but also provide practical tools for pollution control, particularly in regions with limited resources and infrastructure.

3. Methodology

The proposed Floating Water Waste Extractor system utilizes a coordinated process for waste collection from water surfaces, as illustrated in the block diagram in Fig 1, Floating debris is gathered by a conveyor belt mechanism, powered by DC motors, which moves the waste into a designated trash holder for secure storage. The system's propulsion is facilitated by propellers, allowing the extractor to navigate effectively across water bodies. The entire device is powered by batteries, ensuring continuous operation and stability in various water conditions. This integration of conveyor and propulsion systems provides an efficient, autonomous solution for surface-level waste removal, aiding in water pollution management. The functional details and interactions between components are further demonstrated in the accompanying block diagram.

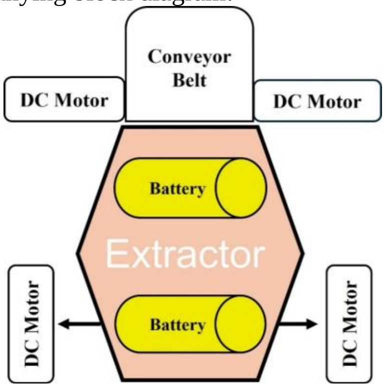

Fig.1 Block diagram of the proposed prototype floating water waste extractor.

In Fig. 2a, the layout of the floating water waste extractor is shown, featuring key components like the trash holder, conveyor belt, DC motor, wheels, and propeller. The 5-volt DC motor powers the conveyor belt, which collects floating debris and directs it into the trash holder. The rear propeller allows for controlled navigation across the water's surface to target polluted areas. Fig. 2b, provides a cross-sectional view of the supporting wheels, which maintain stability during operation and help the device handle uneven surfaces. Fig. 2c, offers a top view, showcasing the compact design and the approximate length of 20 inches while emphasizing the optimal arrangement of components for efficient waste collection. Overall, the device is designed to significantly reduce water pollution.

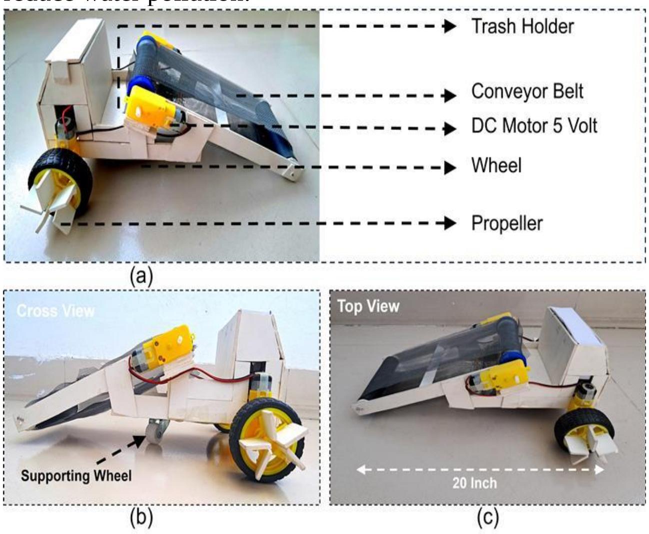

Fig. 2 Views of the floating water waste extractor prototype. (a) Side view showing the trash holder, conveyor belt, 5V DC motor, wheels, and propeller for waste collection and movement, (b) Cross view highlighting the supporting wheel for added stability, (c) Top view illustrating the 20-inch length and compact arrangement of components for efficient surface waste removal.

4. Result Analysis

The floating water waste extractor was rigorously tested, confirming its reliability in real-world scenarios. With its conveyor belt system, DC motors, and navigation propeller, it efficiently captures and transports floating debris. Each component is essential for its effectiveness in autonomous waste collection across various water conditions. In Fig. 3a, the extractor captured a pen cap (0.001 kg), showcasing its ability to detect and collect small, low-density items. This is significant as lightweight debris often evades traditional cleanup methods due to buoyancy and scattering. The extractor's success highlights its precision and adaptability in tackling micro-level pollutants. In Fig. 3b, a plastic ball (0.003 kg) was collected with ease, highlighting the extractor's proficiency in capturing rounded objects. The rounded shape of the plastic ball posed a unique challenge; however, the device efficiently managed to trap it. This test illustrates the extractor's versatility in handling a variety of shapes, a crucial feature for dealing with diverse forms of floating waste. In Fig. 3c, the device successfully retrieved a plastic spoon (0.003 kg), showcasing its capacity to manage elongated and irregularly shaped items. The spoon's shape, which could potentially hinder collection by traditional methods, was effectively captured by the extractor, reflecting the device's robust engineering in adapting to different item geometries on the water surface. In Fig. 3d, the extractor captured a plastic cap (weighing 0.005 kg) demonstrating its capacity to handle slightly denser items that may partially submerge.

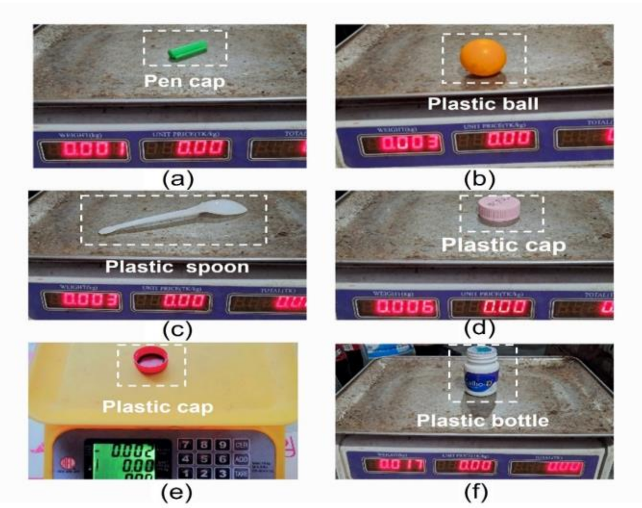

Fig. 3 Test objects are used to evaluate the performance of the floating water waste extractor. (a) Pen cap (0.001 kg), (b) Plastic ball (0.003 kg), (c) Plastic spoon (0.003 kg), (d) Large plastic cap (0.006 kg), (e) Small plastic cap (0.002 kg) and (f) Plastic bottle (0.017 kg).

These items represent typical floating debris of various shapes and weights, enabling a comprehensive assessment of the extractor's capability to capture common water pollutants effectively. In Fig. 3d, the extractor captured a plastic cap (weighing 0.005 kg) demonstrating its capacity to handle slightly denser items that may partially submerge. This test emphasizes the system's robustness in retrieving waste that remains afloat yet sinks partially due to its weight. In Fig. 3e, a larger plastic cap (weighing 0.006 kg) was successfully collected, further verifying the extractor's ability to manage slightly heavier items within its operational capacity. This test demonstrates the device's adaptability across a range of weights, ensuring comprehensive waste collection in polluted waters. In Fig. 3f, the extractor was challenged with a small plastic bottle (weighing 0.017 kg). Despite the increased weight, the extractor efficiently retrieved the bottle, showcasing its ability to handle larger floating items. This test indicates the upper limit of the extractor's collection range, illustrating its capability to manage larger pollutants without compromising functionality. These tests collectively demonstrate the floating water waste extractor's versatility and effectiveness in capturing a wide array of floating debris, from small plastic fragments to larger items. The results documented in these figures highlight the device's potential to make a significant impact on reducing surface-level pollution, particularly in regions where traditional cleanup approaches may fall short. In Fig. 4a, The extractor is shown approaching a floating plastic lid and a plastic ball. This image illustrates the device's capability to identify and navigate multiple types of debris simultaneously. The system's precision in maneuvering towards scattered items highlights its potential to handle dynamic water surfaces where pollutants are dispersed. In Fig. 4b, The plastic lid is successfully collected within the trash compartment, showcasing the device's secure containment mechanism. By transferring the item from the water surface into the collector, the extractor ensures that captured debris remains contained and prevents it from drifting back into the water. This phase highlights the importance of reliable retention, crucial for effective pollution control. In Fig. 4c, A plastic spoon is positioned on the conveyor belt, about to be transferred into the trash compartment. The spoon's elongated shape, which can be challenging for traditional collection methods, is efficiently managed by the conveyor mechanism. This test illustrates the extractor's adaptability in handling irregularly shaped items, demonstrating its robust design to accommodate a variety of debris geometries. In Fig. 4d, The extractor approaches the floating plastic bottle, however with several attempts it fails to capture the bottle showcasing its inability to manage larger, bulkier items. This demonstrates the operational limit of the extractor. The results confirm the device's operational versatility, reliability, and potential as a practical, low-cost solution for surface-level water pollution control. This adaptability makes the extractor a valuable tool for environmental cleanup in areas where traditional waste management infrastructure may be lacking or insufficient.

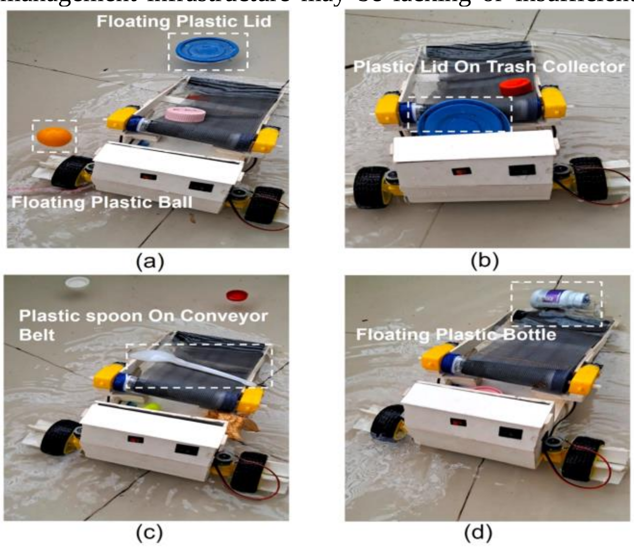

Fig. 4 Operational demonstration of the floating water waste extractor capturing various debris. (a) Extractor approaching a floating plastic lid and plastic ball, (b) Plastic lid collected in the trash compartment, (c) Plastic spoon positioned on the conveyor belt for transfer, (d) Plastic bottle captured on the conveyor belt.

In Fig. 5. The performance evaluation of the floating water waste extractor is illustrated by tracking its success rate over five attempts. In the first attempt, the extractor achieved a 100% success rate, demonstrating optimal performance in capturing debris. In the second attempt, the success rate decreased to 60%, indicating a slight reduction in effectiveness. The third attempt showed an improvement, with the success rate rising to 70%, reflecting partial recovery. By the fourth attempt, the extractor reached an 80% success rate, indicating further stability and enhanced performance. In the fifth and final attempt, the extractor returned to near-perfect functionality with a success rate close to 100%. demonstrating optimal performance in capturing debris.

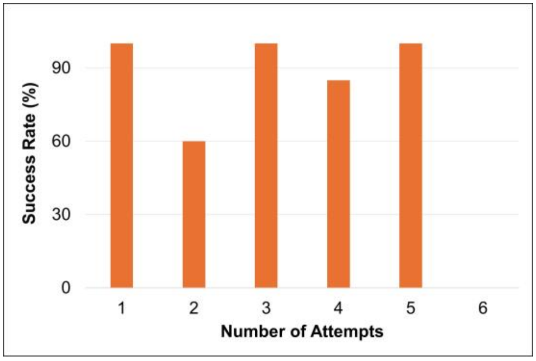

Fig. 5 Success rate of the floating water waste extractor across multiple attempts.

5. Project Finance

The primary objective of this project was to develop an efficient floating water waste extraction system, with the cost analysis focused on acquiring the essential components required for its implementation. The estimation of project costs involved a comprehensive research process, which included an in-depth review of materials offered by various suppliers in Bangladesh and India. This analysis involved a detailed comparison of prices for key components, including motors, sensors, and structural parts, against their equivalent options available in the Indian market. Such an extensive approach enabled a thorough understanding of the financial aspects associated with component procurement, ensuring an optimal balance between cost-effectiveness and performance for the system's successful deployment

Table 1 The final cost for the project and analysis

Name of component	Quantity Used	Proposed System (in BDT)	Equivalent System (India) (in BDT)
DC Motor (5V)	4	312	720
Battery	1	90	320 (lithium ion)
Wheel	1	480	950 (Alloy Wheel)
Propeller	1	300	700 (Blade Propeller)
Trash Holder	1	570	950 (Trash Bin)
Total	**1 unit**	**1752**	**3640**

In Fig. 6. The floating water waste extractor's error rate is evaluated in relation to debris weight. For debris under 1 gram, the system shows a minimal error rate, indicating high accuracy in capturing lightweight items. However, as debris weight increases, the error rate rises sharply, reaching approximately 40% at 5 grams. The error continues to escalate with weight, peaking at 100% around 15 grams, indicating the upper limit of the extractor's effective weight range. This analysis highlights the extractor's optimal performance with lighter debris, while revealing reduced efficiency as weight approaches the system's threshold. These findings suggest the device's best application lies in capturing lightweight, floating pollutants, making it particularly suited for environments with low-density debris.

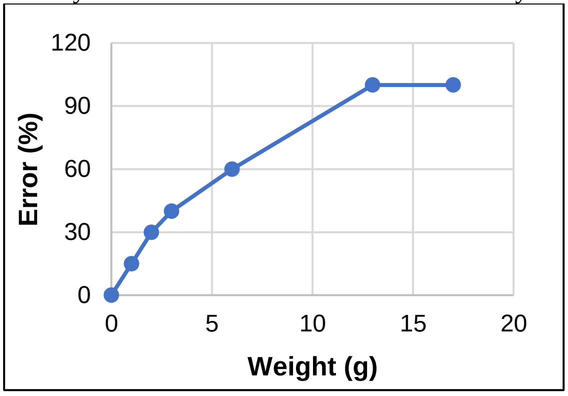

Fig. 6 Error in debris collection relative to weight

6. Future Work

Future work on the floating water waste extractor will focus on enhancing its debris handling capacity, aiming to capture larger and heavier waste by optimizing the conveyor system and integrating stronger materials. Efforts will also be made to improve energy efficiency, extending operational time for prolonged autonomous use. Advancements in navigation and detection will be pursued by incorporating advanced sensors, such as sonar or lidar, for more accurate debris identification, even in challenging conditions. Rigorous testing across various water environments, including high-flow areas, will be conducted to ensure robustness. Additionally, the extractor's size and weight will be reduced for greater portability, and eco-friendly materials will be explored to minimize environmental impact. These enhancements will make the device a more efficient, adaptable, and sustainable solution for water pollution control.

7. Conclusion

The proposed floating water waste extractor successfully achieved its primary objectives, addressing significant challenges through comprehensive testing and analysis. The extractor consistently demonstrated that future improvements should focus on expanding their capacity to handle heavier waste. The system's design demonstrated versatility, effectively capturing a range of shapes, including irregular and rounded items like plastic spoons and balls. While it was able to capture these objects with precision, larger, bulkier debris posed a challenge, where the extractor failed to collect the items despite multiple attempts. This performance gap highlights a key area for future development: enhancing the device's ability to manage larger or denser waste, which will increase its applicability across a broader range of water pollution scenarios. Testing across multiple trials revealed variability in success rates, ranging from 60% to nearly 100%, reflecting the impact of environmental conditions and operational factors. Nevertheless, these results affirm the extractor's reliability in ideal conditions, reinforcing its potential as a cost-effective and scalable solution for water pollution management, particularly in resource-limited regions. A cost analysis further confirmed the system's financial viability, with low-cost components sourced from local markets making it an accessible option for deployment in developing regions. Future work will focus on several key improvements: increasing the weight-handling capacity of the extractor, optimizing its energy efficiency for prolonged autonomous operation, and integrating advanced sensors for better detection and navigation in dynamic water conditions. Additionally, efforts will be made to reduce the size and weight for enhanced portability, and to explore the use of eco-friendly materials to minimize its environmental footprint. The floating water waste extractor represents a significant advancement in addressing surface-level water pollution. It offers a practical, affordable, and adaptable solution for mitigating floating waste, especially in areas where traditional cleanup methods are impractical or unavailable. While there are limitations in handling larger debris, the extractor’s demonstrated effectiveness for lightweight pollutants and its potential for scalability provides a strong foundation for future advancements in autonomous, low-cost aquatic waste management technologies.

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