

Original Research

Received 25 June 2026

Revised 22 July 2026

Accepted 05 Aug 2026

Natural Resources for Human Health 2026, Vol. 6 (16s): 913–920

KEYWORDS:

marine debris; floating waste; tidal current; automated waste collector; docking area; prototype testing

Design and Performance Evaluation of a Seawater Waste Contraption for Floating-Waste Collection in Docking Areas

Antonio E. Morales¹, Joyce P. Jardeleza², Richard Kenneth F. Salas III³, Mandy Ysmael T. Sobrepeña⁴, Ronnie M. Cabalum⁵

¹⁻⁵Department of Electrical Engineering, College of Engineering, Western Institute of Technology, Luna Street, La Paz, Iloilo City 5000, Philippine

ABSTRACT: Marine debris commonly accumulates in calm coastal and docking areas where tidal currents reverse direction. This study designed and evaluated an automated seawater waste contraption that uses current-responsive doors and a screened basket to collect floating and semi-submerged waste. We assessed an experimental prototype in a controlled environment using opposing electric fans to simulate bidirectional tidal flow and 150 pieces of crumpled paper per trial as surrogate waste. We evaluated three test conditions in five trials each: an unrestricted bank configuration, a configuration with guiding walls that directed the simulated current toward the basket opening, and a door-retention test during current reversal. The unrestricted configuration produced a mean collection efficiency of 28.27% (SD = 7.78), whereas the guiding-wall configuration achieved 77.87% (SD = 10.85), representing an improvement of 49.60 percentage points. The bidirectional door mechanism retained all 150 pieces in every trial, corresponding to 100% retention reliability. The findings indicate that the device can prevent collected waste from escaping during simulated current reversal. However, its collection efficiency depends strongly on channel geometry and the use of flow-guiding structures. The prototype may be applicable to calm docking areas, canals, creeks, and tidal coastal communities when integrated with trap lanes or guide walls. Because the tests used airflow and paper substitutes rather than seawater and actual marine debris, field-scale hydrodynamic, corrosion, electrical-safety, and durability testing is required before deployment.

1. INTRODUCTION

Technological modernisation has made production more efficient and has expanded the use of low-cost, durable materials such as plastics. These properties make plastics useful in storage, packaging, and manufacturing; however, their persistence in the environment also makes them a major source of pollution (ChemicalSafetyFacts.org, 2021; National Geographic Society, 2012). Marine debris is composed largely of plastic-based materials, together with wood, metal, garments, rubber, and other floating or semi-submerged waste (Ocean Health Index, n.d.).

Marine plastic pollution damages aquatic habitats and affects fisheries by entangling organisms, obstructing sunlight, damaging coral reefs, and introducing persistent debris into feeding environments (MarineSafe, 2016; Lamb et al., 2018; Slat, 2021). The problem is especially relevant to the Philippines because of its extensive coastline, dependence on marine resources, and documented volume of mismanaged plastic waste entering waterways (Oceans Asia, 2021; Suh & Pomeroy, 2020). Waste transported through creeks, rivers, drainage canals, and coastal waterways often accumulates near docking areas where flow conditions are relatively calm and tidal currents repeatedly reverse.

The seawater waste contraption evaluated in this study was designed around tidal-current reversal. During one half of a tidal cycle, the door facing the incoming current opens to admit floating waste while the opposite screened door remains closed.

When the current weakens and reverses, the first door closes to retain the collected material, and the opposite door opens for the new flow direction. Electric motors, a paddle-type current sensor, and a control panel provide automatic and manual operation.

This study aimed to: (1) construct a prototype seawater waste contraption for collecting floating waste in docking or tidal areas; (2) demonstrate the functionality of the screened basket and bidirectional door mechanism; and (3) evaluate collection and retention performance through controlled observation and descriptive analysis. The study was limited to a prototype tested with airflow from electric fans as a substitute for water current and crumpled paper as surrogate floating waste.

2. LITERATURE REVIEW

2.1 Marine Debris and Plastic Pollution

Marine debris refers to persistent manufactured or processed solid material that enters coastal and ocean environments. Plastics are especially problematic because they are lightweight, durable, and resistant to decomposition. Urban runoff and improper waste disposal carry plastic bottles, bags, packaging, and other debris into rivers and coastal waters, where they may float, become semi-submerged, or settle on the seabed (Clean Water Action, 2017; Oceans Asia, 2021).

Ecological effects include entanglement, ingestion, reduced sunlight, degraded coral habitats, and increased exposure of aquatic organisms to pollutants and disease. Plastic waste has been associated with increased disease incidence in coral reefs, while floating debris can travel long distances and become concentrated by waves and currents (Lamb et al., 2018; Peytavin, 2021).

2.2 Existing Marine-Waste Collection Technologies

Existing marine-waste technologies include suction-based harbour bins, autonomous collection vessels, and remotely operated surface-cleaning systems. Examples described in the literature include SeaVax, the Seabin V5, System 001/B of The Ocean Cleanup, FRED, and the Clean Sea Robot (Chow, 2016; Seabin, 2019; The Ocean Cleanup, 2019; Mayer, 2020; Osborne, 2020). These technologies demonstrate that marine debris can be intercepted through pumping, suction, guided movement, or robotic collection.

2.3 Research Gap and Design Rationale

Many established systems depend on continuous pumps, autonomous navigation, complex sensing, or large-scale infrastructure. These requirements may increase capital cost, energy demand, and maintenance complexity for small coastal communities. The present device investigates a mechanically simpler approach that uses the direction of the existing current to admit waste and screened doors to prevent its release during reversal. Its practical performance therefore depends not only on the door mechanism but also on whether the waterway geometry or auxiliary guide structures direct debris toward the collection basket.

3. METHODOLOGY

This section presents the research design, prototype description, electrical control system, controlled test arrangement, test procedures, and performance measures used to evaluate the seawater waste contraption.

3.1 Research Design

The study used an experimental prototype-testing design. The independent variable was the configuration of the simulated waterway and flow guidance, while the primary outcomes were waste-collection efficiency and door-retention reliability. Each setup was tested in five trials under a controlled indoor environment.

3.2 Prototype Description and Operating Principle

The prototype consisted of a central support structure, a rotating arm, a waste-collection basket, screened directional doors, electric motors, a paddle-type flow sensor, and a control panel. The control system allowed automatic and manual operation. In automatic mode, the door facing the detected current opened while the opposing door remained closed. When the current diminished or reversed, the open door closed to retain waste and the opposite door became available for the next flow direction.

Figure 1 Prototype seawater waste contraption used in the controlled testing environment.

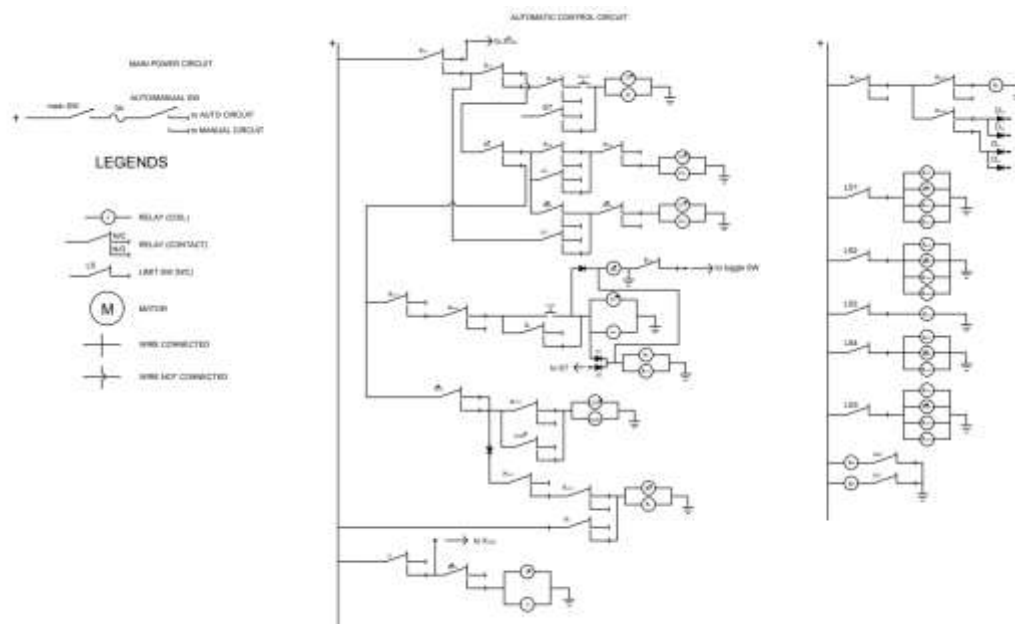


3.3 Electrical Control System

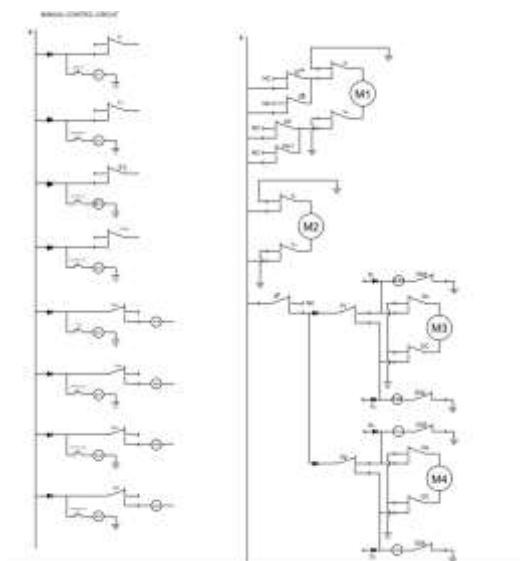
The electrical design included separate automatic and manual control circuits for the motors and directional doors. The automatic circuit used sensing and relay logic to select the door associated with the detected current direction, while the manual circuit allowed direct operator control for deployment, retrieval, rotation, and door actuation.

Figure 2 Automatic and manual control circuits of the prototype.

(a) Automatic control circuit



(b) Manual control circuit



3.4 Controlled Test Arrangement

The prototype was installed in a cardboard assembly representing a bank or waterway. Two electric fans positioned on opposite sides produced sequential airflow to simulate the two directions of a tidal cycle. The airflow actuated the paddle sensor and opened the appropriate door. Crumpled paper pieces were used as lightweight surrogate debris. We introduced 150 pieces in each trial.

Figure 3 Controlled airflow arrangement with the prototype, simulated bank, and opposing electric fans.



3.5 Test Procedures

Setup 1 - Unrestricted bank configuration. The simulated bank was wider than the basket opening. For each trial, 150 pieces of crumpled paper were introduced and blown toward the basket without guide walls. We recorded the number of pieces recovered.

Setup 2 - Guided-flow configuration. The test procedure of Setup 1 was repeated, but guide walls were introduced to redirect airflow and surrogate waste toward the basket opening. The number of pieces recovered was recorded.

Setup 3 - Door-retention test. We placed 150 pieces inside the basket. Airflow was applied from one side, stopped, and then reversed using the opposing fan. This cycle was repeated while observing whether any material escaped. The test assessed whether the doors could retain collected waste during current reversal.

3.6 Performance Measures and Data Analysis

Collection efficiency was computed as the number of pieces recovered divided by 150 and multiplied by 100. Retention reliability was computed as the number of pieces remaining in the basket after simulated current reversal divided by 150 and multiplied by 100. Results were summarised using counts, percentages, means, ranges, and sample standard deviations. No inferential statistical test was applied because the study was a small-scale prototype evaluation with five trials per condition.

4. RESULTS

4.1 Trial Results

The trial-level data show marked differences between the unrestricted and guided-flow configurations, while the door-retention condition produced complete retention in every trial.

Table 1 Trial-level collection and retention results. Each trial used 150 surrogate waste pieces.

Trial	Setup 1: Recovered, n (%)	Setup 2: Recovered, n (%)	Setup 3: Retained, n (%)
1	53 (35.3)	120 (80.0)	150 (100.0)
2	37 (24.7)	137 (91.3)	150 (100.0)
3	42 (28.0)	104 (69.3)	150 (100.0)
4	54 (36.0)	126 (84.0)	150 (100.0)
5	26 (17.3)	97 (64.7)	150 (100.0)

Table 2 Descriptive summary of prototype performance across five trials per condition.

Condition	Total retained/recovered	Mean (%)	SD	Range (%)
Setup 1: unrestricted bank	212 / 750	28.27	7.78	17.33-36.00
Setup 2: guided flow	584 / 750	77.87	10.85	64.67-91.33
Setup 3: door retention	750 / 750	100.00	0.00	100.00-100.00

4.2 Collection Efficiency

The unrestricted bank configuration recovered 212 of 750 introduced pieces across five trials, corresponding to a mean efficiency of 28.27% (SD = 7.78). Trial efficiencies ranged from 17.33% to 36.00%. The low recovery rate indicates that most surrogate waste bypassed the basket when the collection opening occupied only a limited portion of the simulated channel.

With guide walls, the prototype recovered 584 of 750 pieces and achieved a mean efficiency of 77.87% (SD = 10.85). This was 49.60 percentage points higher than Setup 1 and approximately 2.75 times the unrestricted mean. The guided-flow condition consistently directed more debris into the collection opening.

4.3 Door-Retention Reliability

The door-retention test achieved 100% reliability in all five trials. All 150 pieces remained inside the basket during each airflow-reduction and reversal sequence, and no pieces escaped. The result confirms that the screened bidirectional doors performed their intended retaining function under the controlled test conditions.

4.4 Preliminary Design Calculations

The source design used a 2 kg basket-body mass and a gravitational acceleration of 9.8 m/s^2 , producing a nominal weight force of 19.6 N. Distributed over a reported area of 0.18 m^2 , this corresponds to an average nominal pressure of approximately 108.9 Pa. A separate geometric estimate produced a preliminary basket capacity of 0.60 kg. These values are preliminary design estimates, not validated structural ratings.

5. DISCUSSION

5.1 Performance Interpretation

The large difference between the two collection setups shows that channel geometry is a primary determinant of system performance. The prototype did not actively draw debris from the full width of the simulated bank; therefore, recovery was limited when debris could pass outside the basket opening. Guide walls increased recovery by concentrating the flow and surrogate waste toward the collection zone. In an actual installation, booms, trap lanes, or tapered guide structures would be integral components of the system, not optional accessories.

The complete retention result supports the basic operating principle of alternating directional doors. A door can admit debris while flow is present, then close as the flow weakens or reverses to prevent collected material from returning to the waterway. This behaviour distinguishes the concept from continuously pumped harbour bins because the device relies primarily on current direction and mechanical retention rather than continuous suction (Seabin, 2019).

5.2 Engineering and Deployment Implications

The concept appears most appropriate for calm and geometrically constrained waterways, including small docking areas, tidal canals, creeks, and coastal drainage outlets. Successful deployment would require corrosion-resistant materials, protected electrical equipment, reliable motor and limit-switch operation, accessible waste retrieval, and safe maintenance procedures. Guide structures should be designed using measured current velocity, water depth, debris loading, tidal range, and navigational requirements.

5.3 Limitations

The main limitation is using electric-fan airflow instead of actual water current. Air and water differ substantially in density, drag, turbulence, buoyancy, and the forces exerted on debris and mechanical components. Crumpled paper also does not represent the size, shape, density, water absorption, entanglement behaviour, or biological contamination of real marine waste. The tests therefore establish proof of concept but do not demonstrate field-scale hydraulic performance, structural durability, corrosion resistance, or long-term electrical reliability.

6. CONCLUSION

The prototype seawater waste contraption demonstrated that a bidirectional, sensor-controlled door mechanism can retain floating surrogate waste during simulated tidal-current reversal. The unrestricted configuration showed low collection efficiency, while adding guiding walls increased mean recovery from 28.27% to 77.87%. The door mechanism achieved 100% retention in all five controlled trials. These findings support the feasibility of the operating principle for calm tidal or docking environments, provided that the collection system includes effective flow-guiding structures.

Before field deployment, the prototype should be tested in a controlled water flume and then at an actual docking or tidal site using representative debris types and measured flow velocities. Future development should optimise guide-wall geometry, verify

structural capacity and motor torque, use corrosion-resistant components with suitable ingress protection and grounding, and assess fatigue, biofouling, emergency retrieval, maintenance requirements, worker safety, permitting, and lifecycle cost.

7. DECLARATIONS

7.1 Ethical Approval

This study did not involve human participants, personal data, live animals, or clinical interventions. It evaluated an engineering prototype using simulated airflow and paper-based surrogate waste; formal ethical approval was not required.

7.2 Data Availability

The trial-level data analysed in this manuscript are presented in Tables 1 and 2. The authors may provide additional design documentation, subject to institutional approval.

7.3 Artificial Intelligence Disclosure

AI-assisted tools were used to reorganise the source manuscript into IMRAD format and to support language refinement and document formatting. They did not generate the original experimental data. The listed authors remain responsible for verifying all technical content, calculations, interpretations, citations, and conclusions before submission.

7.4 Conflict of Interest

The authors declare no known conflict of interest related to this study.

7.5 Funding

No external research funding was reported in the source manuscript.

8. ACKNOWLEDGEMENT

The authors acknowledge the original prototype developers - Charlo E. Esmilla, Niko I. Olmedo, Ralph Christian G. Vinzon, and Darwin H. Lumandos - whose design documentation, prototype construction, and controlled-test data formed the technical basis of this IMRAD manuscript. The authors also acknowledge the support of the Western Institute of Technology, College of Engineering, Department of Electrical Engineering.

REFERENCES

- [1] ChemicalSafetyFacts.org. (2021, July 19). Plastics: Uses, benefits, and chemical safety facts. <https://www.chemicalsafetyfacts.org/plastics/>
- [2] Chow, L. (2016, February 19). Solar-powered vacuum could suck up 24,000 tons of ocean plastic every year. EcoWatch. <https://www.ecowatch.com/solar-powered-vacuum-could-suck-up-24-000-tons-of-ocean-plastic-every--1882175554.html>
- [3] Clean Water Action. (2017, December 20). The problem of marine plastic pollution. <https://www.cleanwater.org/problem-marine-plastic-pollution>
- [4] Gahl, W. (n.d.). Vacuole. National Human Genome Research Institute. <https://www.genome.gov/genetics-glossary/Vacuole>
- [5] Lamb, J. B., Willis, B. L., Fiorenza, E. A., Couch, C. S., Howard, R., Rader, D. N., True, J. D., Kelly, L. A., Ahmad, A., Jompa, J., & Harvell, C. D. (2018). Plastic waste is associated with disease on coral reefs. *Science*, 359(6374), 460–462. <https://doi.org/10.1126/science.aar3320>
- [6] MarineSafe. (2016, April 18). How ocean pollution impacts marine life - and all of us. <http://www.marinesafe.org/blog/2016/04/18/how-ocean-pollution-impacts-marine-life-and-all-of-us/>
- [7] Mayer, L. (2020, August 4). “Vacuum cleaner” for the ocean. *Aquaculture North America*. <https://www.aquaculturenorthamerica.com/vacuum-cleaner-for-the-ocean/>
- [8] National Geographic Society. (2012, October 9). Pollution. <https://www.nationalgeographic.org/encyclopedia/pollution/>
- [9] Ocean Health Index. (n.d.). Trash pollution. <http://www.oceanhealthindex.org/methodology/components/trash-pollution>

- [10] Oceans Asia. (2021, June 28). Plastic pollution. <https://oceansasia.org/plastic-pollution/>
- [11] Peytavin, A. (2021, June 15). Where does my plastic end up in the ocean? The Ocean Cleanup. <https://theoceancleanup.com/updates/where-does-my-plastic-end-up-in-the-ocean/>
- [12] Port, J. (2017, July 4). How do vacuum cleaners work? Cosmos Magazine. <https://cosmosmagazine.com/science/engineering/how-do-vacuum-cleaners-work/>
- [13] Productivity Inc. (2020, October 19). Benefits of automation: Robotic manufacturing automation, robotics & automation solutions. <https://www.productivity.com/benefits-of-automation/>
- [14] Seabin. (2019, April 10). The Seabin V5. <https://seabinproject.com/the-seabin-v5/>
- [15] Slat, B. (2021, September 16). Why we must clean the ocean garbage patches. The Ocean Cleanup. <https://theoceancleanup.com/updates/why-we-must-clean-the-ocean-garbage-patches/>
- [16] Suh, D., & Pomeroy, R. (2020). The projected economic impact of climate change on marine capture fisheries in the Philippines. *Frontiers in Marine Science*, 7, 232. <https://doi.org/10.3389/fmars.2020.00232>
- [17] The Ocean Cleanup. (2019, October 2). The Ocean Cleanup successfully catches plastic in the Great Pacific Garbage Patch. <https://theoceancleanup.com/updates/the-ocean-cleanup-successfully-catches-plastic-in-the-great-pacific-garbage-patch/>
- [18] Usborne, S. (2020, June 4). Floating vacuum cleaners. LGT Group. <https://www.lgt.com/en/magnet/sustainability/floating-vacuum-cleaners/>