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# Design and Fabrication of a Garbage Lifting Equipment for Collecting Plastic Waste in Lake Matano, Indonesia

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*Abstract*

A pile of plastic waste has been seen across the shore of Lake Matano. This has become the result of local people's bad behavior for years for not throwing their garbage in its place. The waste has been carried by the stream and forms a disturbing plastic pile along the shore which had raised some environmental concerns over this behavior. Therefore, this requires serious attention particularly from the community and local government for a solution. There have been some actions taken for trying to solve it, however, a similar pile is still found in some hotspots. There has been some limitation to those actions, for example, to reach areas under the water that has already been mixed with mud for a long time and those which has been stacked under the houses of the local's residents. This research aims to design and Fabrication a garbage collection device in Lake which aims to facilitate the cleaning of the lake, especially garbage that is difficult to reach from the shores of the Matano Lake. A small boat equipped with a conveyor system working with solar energy was successfully made with a size of 3740x2200x800 (L x W x H). A test was done specifically on the weight of the boat which was approximately 198.47kg, with a buoyancy force of 606,53 kg, Then the volume for the hull part would sink whenever reach its capacity of 78.89%. A test was also carried out on the movement of the boat. By attaching a gasoline engine with a capacity of 5.5 HP, we obtain data that the equipment can run at a maximum speed of 2.66 km/hour.

**Keywords:** Garbage, Load, Plastic, Buoyancy, Conveyor

## Introduction

The use of plastic in this decade has greatly increased[1] because this plastic is very economical and has many benefits for its use[2]. This results in high plastic waste generated, according to the Indonesian Ministry of Environment, In 2020, Indonesia's solid waste generation reached 67.8 million tonnes, This number is estimated to continuously grow shortly[3]. Plastic pollution is part of the country's broader challenge of solid waste management. Plastic waste from Indonesia, the world's second-largest plastic waste producer, has become a central concern for environmentalists and researchers[4]. Studies estimate that Indonesia generated 6.8 million tonnes of plastic waste in, 2017, when everyone produces 0.07kg of plastic waste/person/day, and this is growing faster than the 66% rate of increase in overall waste generation rate by 2040[5]. This will lead to plastic making up 17.4% of the total waste composition by 2040[6]. Of all the plastic waste generated, it is estimated that 0.48-1.29 million tons of plastic waste per year leaks into the oceans and lakes, both those carried by rivers[7], as well as waste that is dumped directly on the coast by the people who live there or by beach tourism visitors[8]. In addition, the lightweight and economical nature of plastic causes plastic to become a single-use item, so more and more plastic waste is generated[9]. In addition to the waste that is carried by the water, in the case of the accumulation of garbage in the lake, this occurs due to the behavior of the people who dispose of waste carelessly. It is known that the shores of the lake are generally inhabited by many people as land for building houses, as well as a source of livelihood, including Lake Matano which is located in East Luwu Regency, South Sulawesi. It should be noted that the shores of lakes are generally inhabited by many people as land for building houses, as well as a source of livelihood, Lake Matano is no exception which is located in East Luwu Regency, South Sulawesi[10]. For tens of years, the people lived in the area, and during that time dumping and accumulation occurred in Lake Matano. This is what causes the amount of plastic waste to continue to increase and ultimately causes quite serious environmental problems. The increase in chemical content in Lake Matano water originating from waste has also begun to increase[11].

It's not just plastic waste that accumulates on the shores of the lake, various other types of waste mix together. However, what is most worrying is the type of plastic, because plastic is a material that is difficult for bacteria to decompose and takes tens or even hundreds of years to decompose naturally[12]. For this reason, efforts are needed to remove plastic waste from water which continues to grow every day. Efforts that have been made previously by the regional government are the deployment of heavy equipment to lift the waste that has settled in the Sorowako jetty area, then disposed of at the final disposal site. However, this method is only able to pick up trash in open areas, whereas, in areas where many people's houses are standing above it, this method of

dredging is difficult because it has the potential to endanger residents' homes. Another way is that the local community works together with the Sorowako Diving Club by cleaning up trash by diving and swimming while carrying plastic trash bags. This cleaning method requires a lot of time and effort and is therefore ineffective.

**Literature Review**

Gorane and team[13], designed a machine measuring 1000mm x 450mm x 700mm (L x W x H) to clean the water surface of the Godavari River, India. The machine is operated remotely, to reduce human labor, and speed up the time to cleaning the river. The drive source of this project is a DC motor 12V and 7.6 amperes which are used to drive the gears, water wheel, and collecting mechanism. It also uses 4 motors. 1 motor is installed on the garbage collector, 2 motors are installed on the left and right water wheels and 1 motor is fixed on the conveyor belt with the help of gears and a chain drive mechanism.

Dharmesh N. Kandare and team[14], designed a smaller river cleaning mechanism than that made by Gorane and team made. The main components of this machine are; Battery, Water wheel, Inclined and Flat Conveyors, Trash Rack, Pipping/Air-Tube mechanism with RC Controlled Guider, Wired Control Box, DC Gear Motors and respective electronics elements, and Air tubes/PVC pipes. The system is successfully able to clean the floating solid waste over the river surface more efficiently. This system works towards its social aim of cleaning the rivers & other water bodies. It stimulates the conventionally used mechanisms of using conveyors in its working principles but has an intimidating modification of the Air Tube Piping Guider mechanism for improving its efficiency.

Fitriana and team[15], made a design for a garbage lifter in a reservoir in Malang, East Java, using holo iron as the base frame, limiting plates on the footrests so they are not slippery, plastic barrels as floats using 14 used drums. At the bottom of the trash can, the box is equipped with wheels to make it easier for residents to move garbage and sediment from the water area to the mainland. The maximum weight of the boat shelter is 490 kg. The movement of the boat is done manually, namely using oars.

Sarifuddin and team[16], designed a prototype of a remote-controlled garbage collector using a pneumatic system that resembles an excavator's arm. This system has the advantage because the arm can rotate up to $180^{o}$ making it possible to pick up trash from the left and right without turning the boat.

**Materials And Methods**

In designing a boat (ship), several methods can be used, including comparison methods, statistical methods, trial methods (trial and error/literacy), and complex-simple methods (complex solutions), which will have 4 design stages namely; Concept, Introduction, Contract, and Details[17]. In this study, the initial method was used, namely literature study which was used as sources of information from previous research journals, so that it could be used as a reference and also as a comparison. After that a field survey was carried out to find actual data information by the conditions in the form of; coastal geography, depth, currents, and routes to be passed by the boat, then planning is carried out using a comparison method. After that determine the main size of the boat which will be used as a reference for designing the boat. The design of the boat is planned with the following drawings: lines plan, general plan, determination of the propulsion engine power, modeling of the garbage transport system, and modeling the boat using the **Autodesk Inventor software**. This stage is carried out to draw conclusions based on the data obtained regarding the design of a trash boat that meets the conditions on the Matano Lake Coast.

Calculation And Specification

Technical calculations are carried out on each component of the boat, namely calculating the total weight of the boat, the buoyant force, and the sinking force. The formula used to calculate the buoyant force on the system is as follows[18]:

Buoyant Force

$$F = \left(\frac{\rho_w}{\rho_b}\right) \times w$$

Sinking part

$$F_s = w - F$$

Extra Buoyancy

$$EB = \left(\frac{TF - TF_s}{TF}\right) \times 100\%$$

The volume is given by:

$V = \pi r^2 h$ for cylindrical

and

$V = \frac{1}{3}\pi r^2 h$ for cone

While the weight data is obtained through the volume measurement approach with the following formula:

$$\rho = \frac{W}{V}$$

and the number of parts submerged in water, using the approach of Archimedes' law as follows:

$$F_a = F_b$$

$$\rho_a V_a g = \rho_b V_b g$$

The lifting mechanism used in this project is a conveyor system. For the design of an effective and efficient material handling system that will increase productivity and minimize cost, the guidelines normally followed are; designing the system for continuous flow of material; going in for standard equipment which ensures low investment and flexibility; incorporating gravity stream in material stream framework; and ensuring that the proportion of the dead weight to the payload of material taking care of gear is least.

*Belt Dimension, Capacity, and Speed*[19]

The circumference of the rollers is given by:

$$v = \pi \times d$$

Capacity is the product of speed and belt cross-sectional area Generally, belt capacity (kg/sec) is given by:

$$BC = 3.6 \times A \times \rho \times v$$

The mass of material $M_m$ (live load) per meter (kg/m) loaded on a belt conveyor is given by:

$$M_m = \frac{BC}{3.6 \times v}$$

*Roller diameter*[20]

The correct choice of roller diameter must take into consideration the belt width. The relationship between the maximum belt speed, roller diameter, and the relative revolution per minute is given by:

$$n = \frac{v \times 1000 \times 60}{\pi \times d}$$

The roll diameter for the belt is given by:

$$D = \sqrt{d^2 + (0.001273) \times L \times G}$$

Where,

$$L = (d + \frac{D - d}{2}) \times \pi \times N$$

Power P required for the conveyor to produce lift is given by:

$$P_p = \frac{F_u \times v}{1000}$$

or

$$P_p = \frac{C \times L \times 3.75}{1000}$$

Where,

$$C = \frac{BC}{C_f}$$

$C_f$ is a Capacity factor (1.08)

*Chain & Sprocket*[13]

This project selects the minimum number of teeth on the smallest sprocket, namely 18 teeth, and chain drive speed ratio r=1

Power design $P_d$ using the service factor is determined from:

$$P_d = P_p \times K_s$$

Power design = Rated power x Service factor (Ks)
where,

Service factor (Ks) = (Load factor(K1) x (Lubrication factor (K2) x Rating factor (K3)

The minimum motor power is given by:

$$P_{min} = \frac{P_d}{\eta}$$

The number of revolutions per minute (n) of the motor is given by:

$$n = \frac{9550 \times P_{min}}{M_t}$$

Where, The moment torsion is defined by:

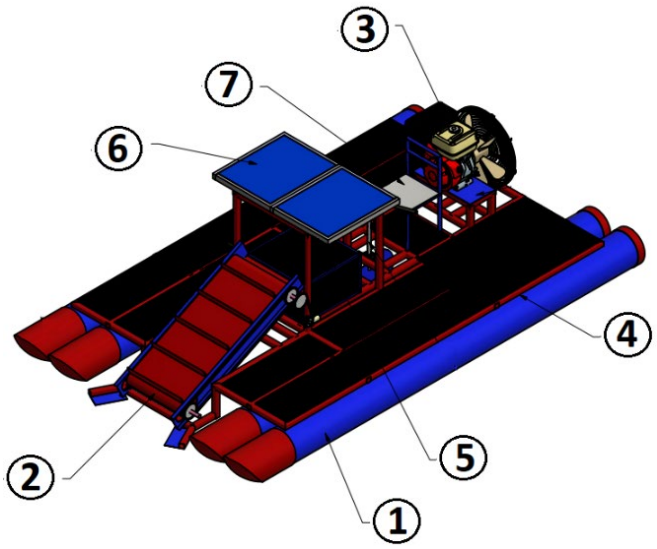
$$M_t = \frac{1}{2} \times D \times (F_u + \mu W g)$$

The motor used is a DC motor. To maintain the supply of power in the battery, charging is carried out from the solar system[21].

## Results And Discussion

For the boat to enter and reach the garbage in the columns of people's houses, the maximum width (B) must be limited. From the results of the field survey, the average distance between the poles in the house was between 2.5 – 3 meters, so the width of the boat (B) was determined to be 2.0 meters, while the length (L) and total height (D) were determined using L/B ratio = 1.90 and L/D = 5.4 as the results of research for multi-hulk type ship, namely L/B = 1.80-3.70 and L/D = 5.25 to 11.24. Thus, the size of the boat obtained is 3800 x 2000 x 700 (L x B x D). By using the **Autodesk Inventor software**, the design of our project shown in Figure 1 is obtained. The main components of the boat consist of; Buoys, Frames, Drive Units, and Lifting Units. The float material was chosen by PVC pipe "D" Type with a diameter of 10 inches.

**Fig.1 3-D Garbage Lifting Equipment**




This Garbage Lifting Equipment consists of several components that produce the overall mass of the system. these components as shown in the figure above can be seen in Table 1, where the heaviest components are the buoy unit, Lifting unit, and main frame respectively.

**Table 1: Main Components of the System**

| No | Component | Material's | Qty | Weight (Kgs) |
|---|---|---|---|---|
| 1 | Buoy unit | Plastic PVC | 12,9 m | 74.65 |
| 2 | Lifting Units | Mild steel, Plastic | 1 unit | 54.50 |
| 3 | Driving engine Units | Aluminium, Mild steel | 1 unit | 17.50 |

| | | | | |
|---|---|---|---|---|
| 4 | Main frame | Mild steel, Hollow bar 40X40 | 40 m | 30.32 |
| 5 | Collecting trash | Mild steel, wire mesh | 1 unit | 7.50 |
| 6 | Solar cell | Glass, Aluminium | 2 unit | 8.50 |
| 7 | Operator's seat | Mild steel Aluminium, | 1 unit | 5.50 |
| Total | | | | 198,47 |

Table 2 shows the design parameters resulting from the results of calculations using the formulas above, which is to find out how much electric motor capacity is required.

**Table 2: Design Values for the lifting units**

| S/N | Parameter | Values |
|---|---|---|
| 1 | Belt width (mm) | 600 |
| 2 | Length of Conveyor (m) | 1.565 |
| 3 | Basic belt length (m) | 3.000 |
| 4 | Belt Thickness (m) | 6.00 |
| 5 | Belt speed (m/sec) | 0.267 |
| 6 | Conveyor capacity (kg/s) | 31.256 |
| 7 | Load due to materials conveyed (kg/m) | 32.500 |
| 8 | Power required by conveyor (W) | 169.844 |
| 9 | The efficiency of reduction gear (drive efficiency) | 0.90 |
| 10 | Power design through the chain & sprocket (W) | 318.458 |
| 11 | Minimum motor power (W) | 353.843 |
| 12 | Torque (Nm) | 27.020 |
| 13 | Motor revolution (rpm) | 125.059 |

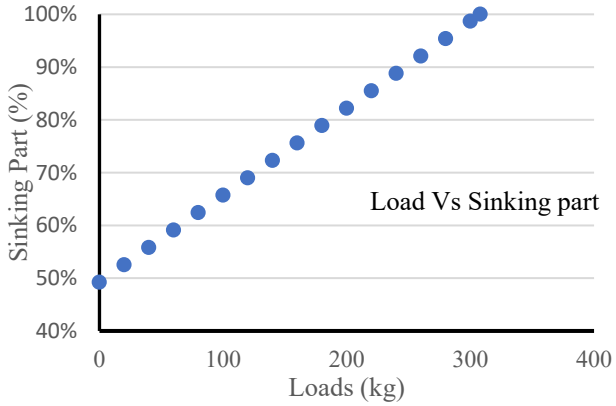
The use of plastic material as a buoy is following research by Chrismianto and team[22] who used plastic material as a hull with the advantage that the ship does not experience deck wetness so that water does not enter the ship. Likewise, Adi and team[23] use plastic pipes as the foundation for a floating house to withstand the load on it. In addition, Plastic can avoid corrosion and has low specific gravity, although it has disadvantages such as lower impact resistance compared to steel. The frame sought to be as light as possible, so it was chosen from a 40mm x 40mm hollow steel bar. The driving unit uses a mechanism adopted from amphibious ships, where the propeller does not touch the water called an *air propeller*[24]. The choice of working mechanism is based on the consideration that in the area there is a lot of garbage that has accumulated at the bottom of the lake which will interfere with the propulsion and steering system if the propeller is placed underwater when the boat is operating. The propeller is transmitted using a pulley and belt system from an internal combustion engine with a ratio of 1:1.

**Fig.2 Fabrication process in the workshop**

**Fig.3 Garbage Lifting Equipment**

To find out the maximum speed of the equipment, we tested it directly on Lake Matano. By attaching a gasoline engine with a capacity of 5.5 HP, we obtain data that the equipment can run at a maximum speed of 2.66 km/hour.

The component that receives buoyant force is the Buoy units, while the other components are considered for external forces acting on the boat. Based on Table 1, the total weight of the boat is 198.47 kg. The calculation of buoyant force is based on the calculation of the total weight of the boat, passengers and the weight of the garbage to be loaded, while the weight of the garbage load is adjusted to the volume of the container prepared on the boat. If we assume an additional 2 people as operators with a weight of 50 kg each, then the total weight is 298.47 kg.




From the results of the buoyancy calculation using the above formulas, the buoyant force (F) = 606.53 kg is obtained, while the sinking force (Fs) is -308.06 kg. The sign (-) indicates the direction of the force opposite to the buoyant force. Extra Buoyancy (EB) is the value of the part of the boat that sinks in the water. From the calculation results, the EB is 0.492, so the number of submerged parts in this design is 49.2%. To determine the weight of the waste that can be loaded by the boat, the formula above can be used again, if the calculation results show EB=1, then the boat's buoy will completely sink. This is not desirable, because it will complicate the boat's movement, so the range of 0.7 to 0.8 is taken. Figure 3 shows the relationship between boat load and the percentage of hull volume that sinks. The heavier the weight of the boat, the greater the volume that sinks. If the boat's load is its weight (198.47) then the part that sinks is only 32.72% and the boat will sink at a load of 606.5 kg, or the total load is 408.05 kg. We assume that 2 operators are required with a weight of 50 kg each, so the total weight of the waste when the boat sinks are 308.05 kg. These conditions have not considered external load factors such as the influence of waves, wind, and other weather factors. With these factors, the load of waste that can still be loaded is 180 kg, where the magnitude of the sinking part for the total weight of the boat and all its cargo (478.47 kg) is 787.29/998 = 78.89%.

## Conclusion

From the description of the discussion above, it can be concluded that the boat is designed to float well on the water of Lake Matano with a maximum load of 308.05 kg, but taking into account external loads and operational conditions, it is recommended to reduce up to 180 kg of waste and 2 people operator (assuming the operator weighs 50 kg). This boat has a width of 2200 mm, which makes it possible to target garbage in the columns of residents' houses so that all areas can be reached. With this project, the process of cleaning up floating garbage on the shores of Lake Matano is easier to do and can be done at any time, so that water

pollution in the coastal areas, which are mostly inhabited by indigenous people, can be maintained. However, this tool still needs to be developed by completing automatic features, so that human operators are no longer needed.

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