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Design and development of trash trap of stream for mini hydro

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A B S T R A C T

The river became increasingly contaminated over the years and in the wake of rapid development in the town. The purpose of this paper is to invent and provide a trash collector for mini hydro that is readily removable so that the trashes collected can be easily disposed of. Design of the trash trap should be compatible with existing stream structures. Trash trap must prevent any trash and debris from passing through the mini hydro. Fieldwork was done at the stream river to investigate the surrounding and stream structure. The data collected were mass of trash collected with diverter and without diverter. A total of 10.0 kg of trashes were collected. The efficiency of the trash trap was calculated by the proportion of the average mass of diverted trashes by the total mass of trapped trashes. The targeted efficiency for this trash trap project is 70.0%. Based on the data collected, the efficiency of this trash trap is 84.12%. The targeted efficiency was achieved and design improvement of this trash trap will be discussed at the recommendation. In conclusion, the trash trap had been proven as a potential solution for the mini hydro machine problem, diverts and prevents most of the trashes from entering the mini hydro and blocked the turbine from rotating.

1. Introduction

A stream is a small body of water with surface water flowing through the canal bed and the banks. It exists on its own and joins a large river with other rivers. Depending on the water source and the climate and geography of the stream, the stream may be permanent or seasonal [1]. Stream is important to flow over these sources of water to the rivers and oceans. However, the stream is exposed to the trash such as food waste, plastics, dried leaves and twigs due to the wastewater from the houses and its environmental surroundings. Besides, the amount of dried leaves and twigs falling into the stream increase when it is surrounded by mangroves and palm oil trees.

Mini hydro is a type of hydro-energy machine installed at the stream to generate electricity using water flow. The turbine transforms the flowing water into rotational energy. The moving shaft of the generator transforms the rotational energy into electricity for daily use. When the flow of water is blocked by the trash, it disrupts the energy generation turbine which consequently affects the performance of mini hydro. The trash causes the turbine blade to stop rotating, resulting in no renewable energy generation. Besides, the trash causes the water inlet of the river to be blocked by a mini-hydro machine. Hence, the trash must be cleaned at least once a day to ensure that the flow of water is in good condition. This indicates that the design of trash trap to block and remove waste from the flow of water in the stream is needed to prevent the operation of mini hydro from being disrupted.

Use of Gross Pollutant Trap (GPT) or trash trap to block the trash from entering the river system has been a common practice around the World. Most of the GPTs are installed at the end of drainage prior to discharge the water containing solid waste from residential area into the river, mainly to prevent water pollution [2]. Meanwhile, the influence of trash to the operation of mini hydro has been neglected, where almost no research has been carried out to adapt the design of trash trap for installment near to mini

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hydro. Besides, almost every existing research in the related field focuses on the performance evaluation of GPT or trash trap, without stressing on the trash trap design and development [2–4]. Therefore, this research initiates the design of trash trap that is applicable for mini hydro.

The aim of this study is to prevent trash from entering the mini hydro plant in the stream. There are three objectives of this project and the first is to design a trash trap for a mini-hydro machine. The second objective is to construct a waste trap for a mini-hydro stream machine. The third objective is to analyze the efficiencies of the trash trap according to the suitability of the surrounding stream.

2. Literature review

2.1. Renewable energy

Energy consumption and the potential for energy savings become more intensive in residential, industrial, commercial and public buildings to improve energy performance nowadays [5]. Renewable energy is a type of energy produced by the use of natural resources. These include hydropower, wind, solar, geothermal and biomass. Renewable energy supply technologies need to be promoted and developed due to some negative and irreversible externalities resulting from conventional energy generation. These technologies may not be compared with conventional fuels in terms of production costs, but they could be comparable in terms of their associated externalities, such as their environmental and social effects [6]. Malaysia ranks 35th in the use of hydropower to generate electricity and uses 93.1% of non-renewable energy to produce electricity. The use of renewable energy to generate electricity in our country needs to be improved [7]. Hydro turbines convert water pressure to mechanical shaft power that can be used to drive a generator or other useful devices.

Hydro power is currently the world's largest source of renewable energy for electricity generation. In the last 50 years, the production of hydro-electricity has increased enormously. In 1950, 340 terawatt-hours (TWh) accounted for about one third of the international demand for electricity. It increased to 1,500 TWh in 1975 and to 2,994 in 2005. This may be equivalent to 15,000 global consumption [8]. There are three types of power generation plants that are run-of-river, reservoir and pumped storage. Reference explained that hydro power plants convert the potential energy contained in water into electricity [9]. The basic principle of hydropower is that if water can be channeled from a higher to a lower level, the resulting potential water energy can be used to perform the operation. If the mechanical component can be moved by the water head, this movement involves converting the potential energy of the water into mechanical energy. Hydro turbines convert water pressure to mechanical shaft power that can be used to drive a generator or other useful devices.

2.2. Trash trap

Trash trap removes water from solid waste, litter, debris and heavy sediment. Some of the advanced design also provides for the separation of liquids to remove oil in water. Collectively, these substances are known to be gross pollutants. Trash trap or GPT can be categorized into a few categories. The categories are floating debris traps, in-pit devices, trash racks and litter control devices, sediment traps and sedimentation reservoirs and fixed trash racks (SBTR Trap) [10]. The categories will be explained in more detail below.

Floating debris traps is a device that captures trash in permanent water bodies with a wide range of catchment areas of more than 200 ha. Booms are the first type of floating debris that only effective as a pollution control measure under certain site conditions such as location relative to major sources, easy access for maintenance and no interference with river traffic. The second type is a bandalong trap. Bandalong has a floating gate at the entrance throat that closes when the tide reverses direction to ensure that floating debris is retained.

In-pit equipment is a device that traps litter and sediment in inlet pits. There are two types of in-pit devices that are trapping gully pits and litter baskets. Trap gully pits are located deeper than standard pits as they trap sediment. Trap gully pits are only useful where the stream system contains but their effectiveness is limited due to the tendency of high flows to enter and move away the sediment and litter collected. Litter Basket is a simple perforated or mesh basket that is installed in existing side entry pits. The size of the basket is chosen to fit the existing size of the inlet pit. This type of device is primarily intended for pipe systems.

Trash rack is a well-known device, especially in Australia. This structure is used to prevent debris from clogging the entrance of stormwater and wastewater. Litter Control Device is a device that has been installed on open channels and pipe drain outlets located in Australia. These devices collect litter, as do trash racks, and can therefore be described as "soft" trash racks.

Sediment trap is a device that removes sediment only and does not remove litter. Sedimentation traps are an enlarged area of the waterway. The purpose of this trap is to reduce the hydraulic gradient in order to reduce the flow velocity and allow the sediment to be trapped and the sediment to be suspended to be removed from the suspension.

SBTR is a combination of the functions of a sedimentation reservoir and a fixed trash rack. The trap was a large concrete lined reservoir designed both to intercept litter, debris and coarse sediment during storm flows and to act as an efficient retarding reservoir. The ongoing development of SBTR type traps in Australia has focused on improving these facilities for ease of maintenance and simplifying the design elements to reduce capital costs.

2.3. Design of waste trap

Waste traps can be designed according to the type of waste that either wet or dry waste needs to be trapped. The best waste trap is that it can collect both wet and dry waste. Waste trap can be designed using one or a combination of screening, water flow, flow separation, sedimentation and flotation. The design of the GPT should be appropriate and convenient depending on the location in which it is to be used. The stream has a slow flow of water, a muddy surface and is surrounded by mangrove trees.

Waste traps are designed to meet the needs of the surrounding area. Some factors need to be considered in gross pollutant traps. Factors are the size of the waste or particles to be caught in that location, the physical space available for the trap, the frequency of storms or other water inflows, the average flow rate, maintenance requirements, maintenance frequency, estimated loading of the waste, the safety of the trap and the aesthetic value of the trap [11].

2.4. Waste trap in Malaysia

River of Life (ROL) is one of the Government of Malaysia's economic transformation projects. The aim of ROL is to transform the Klang River into a vibrant and vibrant waterfront with high economic value. This transformation is divided into three main components: river cleaning, river master planning and beautification, and river development. There are now 117 devices for the trapping of gross pollutants installed in the commercial and residential areas of ROL. Package 4 includes Sungai Klang, Sungai Kemensah, Sungai Gisir and Sungai Sering. Data were collected during maintenance of the GPTs, together with water quality sampling at the inlet and outlet of the River of Life facility [12].

Gross sediments, on the other hand, are inorganic breakdown products from soils, pavements or building materials. For the Klang River, an average of 50–60 tons of garbage is collected daily. With 80 tons of garbage collected from the waste traps along the Klang River and its tributaries, the condition worsens after heavy rainfall. Situations in which floating waste found in the river across the country is common in heavily populated areas such as Kuala Lumpur.

Reference analyzed the GPT system, a development specification set to serve up to a repeat 3-month average catchment period [13]. The main traps are devices designed to slow down the storm water before it reaches the ground or the sewer system, whether mixed or separated. The average catchment area for each GPT unit is approximately 1.8 ha, while the maximum runoff area is 50–80 m. These highly urbanized catchments with various forms of commercial and residential land have been selected to reflect local sources of pollution and potential environmental loads along the Klang Valley.

The research on performance evaluation of GPT in Malaysia is extensive currently. However, there is currently lack of research on the design and development of trash trap. Hence, aiming to solve the issue of performance of mini hydro affected by stream pollution, the study of design and development of trash trap of stream for mini hydro was initiated.

3. Methodology

3.1. Propose design

The problem in river stream is exposed to the trash due to the waste water in the house and its environmental surroundings. Litter in the stormwater system includes human-derived waste that has been illegally dumped into the waterways, including the stream. Debris consists of organic material, including leaves, branches, twigs and grass clippings. A design of a trash trap is proposed to overcome this problem. The design is proposed on the basis of the suitability of the surrounding area. The stream is 4.0 m wide and 0.5 m to 0.7 m deep.

The idea of a trash trap is designed to prevent trash from entering a mini-hydro machine. This trash trap consists of a diverter, trap 1, trap 2 and trap 3. The trash will be diverted by using a diverter located at the inlet of the mini-hydro machine. The trash will be collected using trash trap 1 and trap 2 on the left and right side of the machine. Trap 3 is located inside the mini-hydro inlet to catch the trash that has passed through the diverter. Fig. 1 shows the layout and mechanism of the trash trap. The diverter is made of two 80 mm pvc pipes. Each pipe has a length of 1.5 m and is connected by an L-shaped pvc connector. The end of both pipes is covered by a 40 mm pvc end cap to ensure that the diverter floats and diverts the trash along the stream and prevents it from passing through the mini hydro.

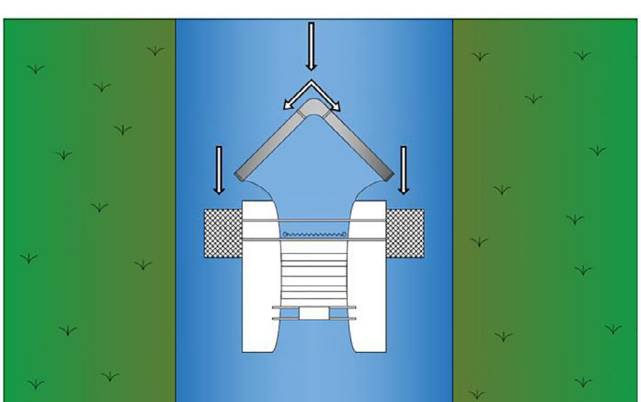

Fig. 1. The mechanism of the trash trap.

Trap 1 and Trap 2 are placed next to the mini hydro. This trap consists of a wire mesh basket and a rack. The trap used to collect the trash is a basket made of mesh wire. The basket structure is made of 15 mm pvc. The mesh size is 10 mm. The basket is 0.6 m in length, 0.3 m in height and width. The basket is inside a rack made of 20 mm pvc. The rack is designed with a wire mesh behind it to ensure that no trash can pass through the trap. Fig. 2 shows the close-up of the wire mesh basket and the rack to trap the trash along the stream.

Trap 3 is placed inside the mini-hydro inlet. This trap consists of 20 mm pvc pipe and wire mesh. Behind this trap, the wire mesh is completely covered to trap the trash that passed through the diverter. Fig. 3 shows the design for the trash trap 3.

3.2. Selection of materials

The material in the trash trap is selected according to the suitability of the surroundings to ensure the durability of the trap. Material selection is a crucial process to ensure the durability of the product in any condition and most importantly, it can be functional.

Most of the trash trap structure is made of pvc pipe. The pvc pipe is selected for a number of reasons. It has a good tensile strength to make sure the structure is strong and also readily available at a low price. The Pvc pipe comes on the market in different sizes. The size of the pipe used in this project is 15 mm, 20 mm and 80 mm. The 15 mm pvc pipe is used as the structure of the trash trap. The 15 mm pvc pipe is used to make a basket frame. Next a 20 mm pvc pipe is used to construct a trash trap rack. Finally, the 80 mm pvc pipe is used as a diverter at the inlet of the mini hydro to prevent trash from passing through it.

The Pvc pipe is connected by a few types of connectors. The type of connector used in this trash trap project is a T-shaped pvc connector and an L-shaped pvc connector. The pvc adhesive will be used to connect the pvc pipe and the connector to strengthen the trash trap.

The trash trap basket is made of pvc galvanized welded wire mesh as shown in Fig. 4. The mesh size of your basket is 10 mm. This wire mesh has a smooth mesh surface, well-proportioned mesh and strong welded points. The joint is soldered tightly, anti-corrosive and anti-rust. Based on the criteria, this type of wire mesh is very suitable for the construction of a trap.

The pipe strap as shown in Fig. 5 is used to hold parts of the trash trap. The strap will be fixed to the pvc pipe by the use of the bolt and nut. The parts of the trash trap will be attached to the mini hydro by attaching the strap to the body.

3.3. Fabrication process

The manufacturing process of the trash trap starts with the accurate measurement of each part of the trash trap. The pipe is cut by the use of a hacksaw. Each pipe was glued to its specific shaped connector using pvc glue. Both L-shaped and T-shaped connectors are used for both basket and rack construction. Next, wire mesh was measured and cut using a wire cutter as measured. The wire mesh was fixed to the frame of the basket by means of cable ties. A wire mesh was tied behind the rack to ensure that no trash can pass through the trap. Fig. 6 below shows a complete basket for collecting the trapped trash and the basket rack. Fig. 7 below

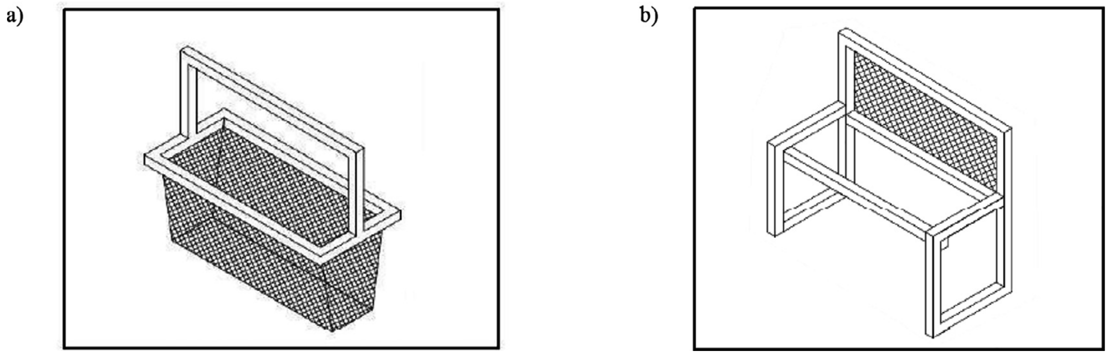

Fig. 2. (a) Wire mesh basket; (b) Rack.

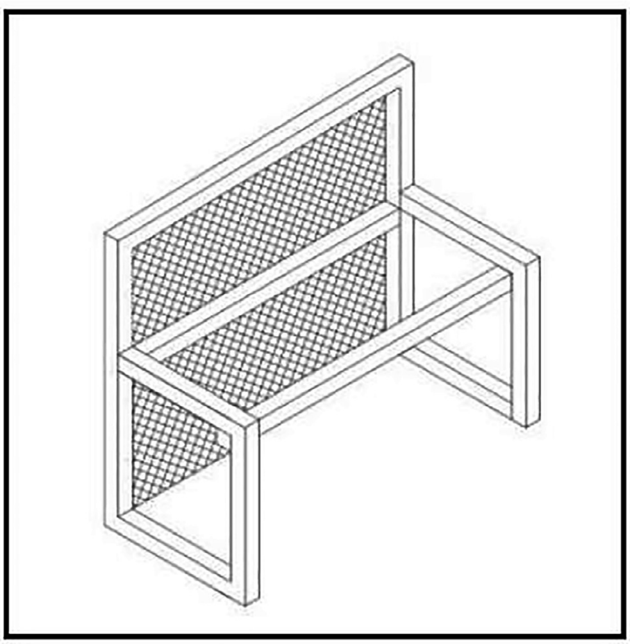

Fig. 3. The design of trap 3.

Fig. 4. Pvc galvanized welded wire mesh.

shows a combination of basket located inside the rack. The basket has a smaller base to fit inside the rack easily.

Fig. 5. Pipe hanger strap.

4. Result and discussions

4.1. Result

The project was completed for 6 consecutive days from 23 November 2019 to 28 November 2019. The data were collected during the high tide of the day. Table 1 below shows the Kukup tide table from 23 November 2019 to 28 November 2019. During the period, average tidal excursions were 0.8 m and 3.1 m during neap and spring tides, respectively. The high tide may run from 3.5 m to 3.6 m during December [14].

A total of 5.1 kg of trash was trapped along the river. Most of the trapped trash consists of twigs, leaves and plastic materials such as bottles and plastic packaging. Table 2 shows the mass of trash trapped for three consecutive days from 23 November 2019 to 25 November 2019. The data were collected approximately every 24 h during the high tide, which was around 9.00 a.m. to 11.00 a.m. A total of 1,3 kg of trash was trapped on the first day. Trap 1 and Trap 2 caught a total of 1.1 kg of trash while 0.2 kg of trash passed through the diverter. The result shows an increase of 0.7 kg of trash on the second day. In total, 2.0 kg of trash was collected which trap 1 and trap 2 managed to catch 1.7 kg of trash while 0.3 kg of trash was trapped in trap 3. On the third day a total of 1.8 kg of trash was successfully trapped. Trap 1 and trap 2 man-

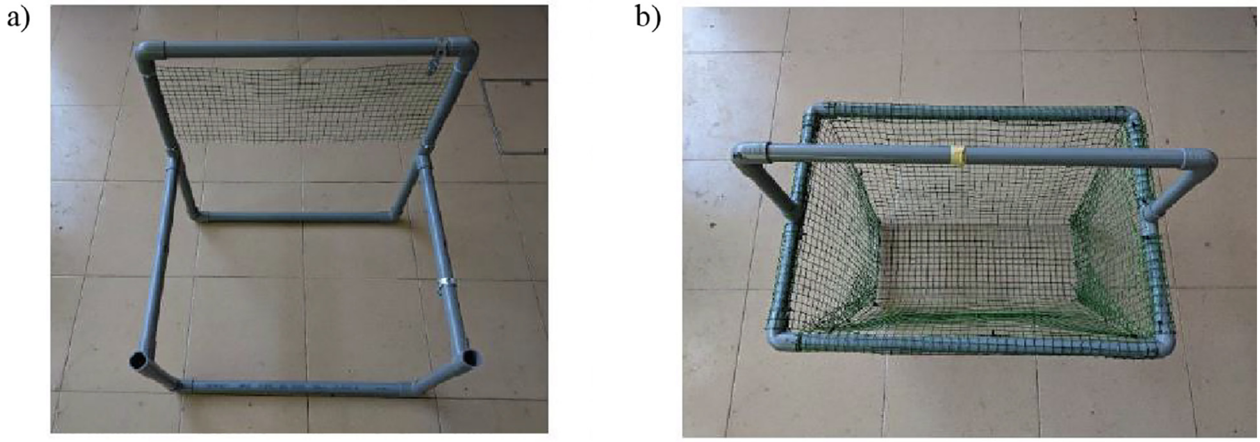

Fig. 6. (a) Basket; (b) Rack.

Fig. 7. Trash trap to collect diverted trashes.

aged to catch 1.5 kg of trashes while trashes that passed through the diverter were 0.3 kg which is the same as the previous day.

Data for collected trash without a diverter (Table 3) shall be taken for three consecutive days from 26 November 2019 to 28 November 2019. The method used to collect the data is the same as the trash collected with the diverter. The data is collected during the high tide of the day which was between 10.30 a.m. and 12.00p.m. A total of 1,5 kg of trash was collected on the first day. Trap 1 and trap 2 managed to catch 0.7 kg of trash while 0.8 kg of trash was trapped in trap 3. A total of 1,6 kg of trash was collected on the second day. Trap 1 and trap 2 managed to catch 0.8 kg of trash and trap 3 caught 0.8 kg of trash which was the same as the previous day. The amount of trash collected is the highest on the third day which was 1,8 kg. Trap 1 and Trap 2 trapped a total of 0.9 kg of trash while Trap 3 successfully trapped 0.9 kg of trash.

4.2. Efficiencies of trash trap

The trapping efficiency of the device is described as the percentage of the total mass of gross pollutants transported by stormwater that the trap maintains. A trap with poor trapping efficiency means that the trap passes through a large proportion of the gross pollutants carried by stormwater and enters downstream water [15].

The data collected for trash trapped without a diverter shows that the total amount of trash for three consecutive days was 4.9 kg. The average amount of trash trapped for these three days is 1.63 kg. Trap 1 and Trap 2 managed to catch 2.4 kg of trash while Trap 3 captured 2.5 kg of trash that had passed through the mini-hydro machine. The average amount of trash passed through the mini-hydro machine was 0.90 kg. Based on the data collected, approximately 55.21 per cent of the trash along the stream passed through the mini-hydro machine on a daily basis.

In the case of trash collected with the diverter, a total of 5.1 kg of trash was successfully trapped in trap 1, trap 2 and trap 3. The average amount of trash trapped per day is 1.70 kg. Trap 3 managed to catch a total of 0.8 kg of trash for three consecutive days. The average amount of trash passed through the mini-hydro machine was 0.27 kg. Based on this data, the waste that was successfully diverted from entering the mini-hydro machine was 4.3 kg, with an average of 1.43 kg per day. Based on the data collected, the efficiency of the trash trap is calculated to be 84.12 per cent. This shows that 84.12 per cent of the trash was successfully diverted and trapped.

Table 1
Tide table at Kukup from 23 November 2019 to 28 November 2019.

Day	Tides at Kukup (time and height)							
	1st Tide		2nd Tide		3rd Tide		4th Tide	
	Time	Height	Time	Height	Time	Height	Time	Height
23 Saturday	02:28	0.84 m	08:57	2.71 m	15:06	1.06 m	21:05	2.67 *m*
24 Sunday	03:28	0.84 m	09:37	2.88 m	15:55	0.74 m	22:06	2.86 *m*
25 Monday	04:16	0.88 m	10:12	3.02 m	16:39	0.46 m	22:57	3.00 *m*
26 Tuesday	04:58	0.96 m	10:46	3.13 m	17:20	0.25 m	23:43	3.06 *m*
27 Wednesday	05:37	1.07 m	11:19	3.2 m	18:01	0.12 m	–	–
28 Thursday	00:28	3.05 m	06:15	1.18 m	11:52	3.23 m	18:42	0.06 m

Table 2
Trash collected with diverter.

Day	Mass of trash trapped			
	Trap 1	Trap 2	Trap 3	Total
Day 1 (23 Nov)	0.7 kg	0.4 kg	0.2 kg	1.3 kg
Day 2 (24 Nov)	1.0 kg	0.7 kg	0.3 kg	2.0 kg
Day 3 (25 Nov)	0.9 kg	0.6 kg	0.3 kg	1.8 kg
Total mass	5.1 kg			

Table 3
Trash collected without diverter.

Day	Mass of trash trapped			
	Trap 1	Trap 2	Trap 3	Total
Day 1 (26 Nov)	0.4 kg	0.3 kg	0.8 kg	1.5 kg
Day 2 (27 Nov)	0.5 kg	0.3 kg	0.8 kg	1.6 kg
Day 3 (28 Nov)	0.5 kg	0.4 kg	0.9 kg	1.8 kg
Total mass	4.9 kg			

5. Conclusion

Based on the results and data analysis, it is clear that the objectives of this project have been achieved. The first objective of this project is to design a trash trap for a mini-hydro machine. The design conceptual design of the trash trap was based on the suitability of the surrounding area. The second objective is to construct a waste trap for a mini-hydro stream machine. The trash trap was constructed using a 15 mm, 20 mm and 60 mm pvc pipe, pipe hanger strap and wire mesh size. Finally, the third objective is to analyze the efficiency of the trash trap according to the suitability of the surrounding stream.

Based on the data collected, the efficiency calculated for the trash trap is 84.12 per cent, while the efficiency target for this project is 70 per cent. Targeted efficiency has been achieved and the design improvement of this trash trap will be discussed in the recommendation below. In conclusion, the trash trap was proven to be a potential solution to the problem of the mini-hydro machine. This trap diverts and prevents most of the trash from entering the inlet of the mini hydro-machine and prevents the turbine from rotating. As a result of this application of the trash trap, the mini-hydro machine is now fully functional and generates renewable energy.

As far as recommendation is concerned, the design of the trash trap must be improved in order to achieve a high percentage of efficiency. Some of the recommendations are listed as follows:

- Wider trap beside the mini hydro machine is needed in order to maximize the area of trash catchment.
- The trash trap needs to be installed firmly to ensure it did not move when trapping the trashes.
- Part of diverter below the water level need to be covered more to decrease the number of trashes passed through the mini hydro machine.

CRediT authorship contribution statement

Mohd Nashruddin Mohd Shah: Conceptualization, Data curation, Formal analysis, Investigation, Project administration, Resources, Validation, Visualization, Writing - original draft, Writing - review & editing. **Faridahanim Ahmad:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Project administration, Resources, Supervision, Validation, Visualization, Writing - review & editing. **Mohd Sufyan Abdullah:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Mohd Kamaruzaman Musa:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Nur Izieadiana Abidin:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Hasnida Harun:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Nor Hazren Abdul Hamid:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Mariah Awang:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Muhammad Ashraf Abdul Rahman:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Nuramidah Hamidon:** Data curation, Formal analysis, Resources, Validation, Visualization, Writing - review & editing. **Fatimah Mohamed Yusop:** Investigation, Resources, Validation, Visualization, Writing - review & editing. **Mohd Syafiq Syazwan Mustafa:** Investigation, Resources, Validation, Visualization, Writing - review & editing. **Nur Atikah Kamil:** Investigation, Resources, Validation, Visualization, Writing - original draft, Writing - review & editing. **Tsu Yian Lee:** Investigation, Resources, Validation, Visualization, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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