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Development of Rainwater Harvesting System for *Sekolah Menengah Kebangsaan Iskandar Syah Melaka*

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Abstract. This paper presents the development of rainwater harvesting (RWH) system at *Sekolah Menengah Kebangsaan Iskandar Syah* (*SMKIS*), Melaka to promote landscape sustainability. The proposed RWH system deployed an elevated tank, a sequential filter, and a storage tank. A fertigation pond and a turbine were installed as part of the RWH system in *Taman Herba* to promote an ecosystem for freshwater habitat and to generate energy. The RWH system was used as an alternative water supply to the *Taman Herba* and the fertigation pond as well as water supply for power generation. It was found that the RWH system has successfully reduced the rainwater flowrate in the existing drainage system by 50.9% and effectively reduced the utility bills for the landscape irrigation and the fertigation pond. The turbine generated 26.6 W power which is adequate to light up a scrolling message board at *Taman Herba*. Both the fertigation pond and the turbine embellished the *Taman Herba* landscape and are a good platform for experiential learning for the secondary students in *SMKIS*.

1. Introduction

Malaysia faces heavy rain during Northeast Monsoon (October to March) every year as compared to Southeast Monsoon (April to September). A part of the rainwater does not drain away from the soil-surface but entered the soil. The quantity of water present in the soil becomes abundance in which sometime leads to flooding risks and soil erosion. Soil erosion problem may occur due to inability of the soil to withstand the heavy raindrop effects [1]. It causes soil detachment and deposition to the lower part of the hill and endanger community nearby.

Soil erosion is a serious concern for *Sekolah Menengah Kebangsaan Iskandar Syah* (*SMKIS*) as the school facilities are located at hillsides. Figure 1 shows the overflow of heavy rainwater and erosion at the hillside whenever heavy rains happened. The heavy, high velocity rainwater exposed the hillsides to soil erosion and caused floods at *Taman Herba* and school facilities as depicted in Figure 2.

Rainwater harvesting (RWH) system is a developed system to minimize flood or utilize the rainwater into various purposes, especially for agriculture and domestic use. The RWH system is potentially great to sustain the hydrological problems due to environmental challenges in some dry climate countries and reduce the soil erosion problem in wet climate. The method of induce, collect, store, and use for various purposes implied to the basic concept of a RWH system [2]. Current works investigated the RWH system for home application which involves the collection of the rainwater from the rooftop [3], and stored in a reservoir or direct infiltration into an aquifer [4] which are then used for lawn irrigation [3], household consumption [5] and house cooling [6].

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Prevention steps such as slope restoration to reduce rainwater erosion in *SMKIS* has started since 2010. However, soil erosion at the hillsides becomes more obvious during monsoon season recently. It is a threat for the pupils, teachers and the school facilities as a whole. A RWH system has been identified as one of the innovative solutions to sustain the landscape and to reduce the impact to the environment by utilizing the abundance of rainwater. Previous research has successfully adopted a RWH system to optimize the abundance of rainwater in hilly community [7]. Thus, the application of a RWH system in the school facilities is very promising. In the present study, a RWH system to mitigate the soil erosion at the *SMKIS* is attempted.



Figure 1. Overflow of the existing draining system during heavy rain and erosion at the hillsides.



Figure 2. Flood at *Taman Herba* and nearby school facilities.

2. Research methodology

This section describes the conceptual design of RWH system with the theoretical description. This study introduces 2D & 2C approaches in the RWH system of *SMKIS*. The main idea is to reduce the rainwater flowrate by diverting and dividing (2D) the rainwater in the existing drainage. The rainwater is then collected and converted (2C) into useful applications. In this study, the concept and benefits of pico hydro system was exploited in the development of a RWH system for a school building. Pico hydro system is a term used to represent a small-scale turbine system without a dam that can generate up to 5kW power [8]. The system is normally built up at rural areas for electricity production [9,10] and for domestic use [11]. The study is fulfilling the gap within the study area of pico hydro in supporting a healthy educational building.

2.1. Conceptual design of RWH

RWH is a process of collecting rainwater and store it for future uses [12]. Basic RWH system consists of a filter and a storage container. This method has a great potential as an alternative water supply to watering the plants at *Taman Herba*. It was also suggested that the RWH system becomes an experiential learning platform for pupils in *SMKIS*. The goal was achieved with the integration of a fertigation pond and a turbine.

The RWS system proposed for *SMKIS* is shown in Figure 3. The initial flowrate of the rainwater was measured at 0.06 m^3/s. It was suggested that a dam is built before the water drainage to slow down the heavy rainwater stream. The overflow in the dam was directed into the normal drainage system. The harvested rainwater in the dam was supplied to a fertigation pond and a turbine in the *Taman Herba*. The installation of the fertigation pond was suggested as freshwater habitats and the turbine was mounted to demonstrate electrical generation.

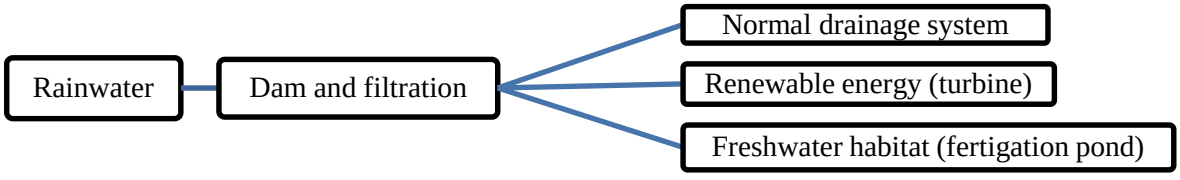

Figure 3. Conceptual design of Rainwater Harvesting system for *SMKIS*.

2.2. Theoretical and actual measurement

The significant of theoretical part is that the generated power can be predicted from the vertical height of the hill before the system being developed. Then, the other parameters such as the pipe diameter and type of pipe were determined to obtained the predetermined power generation. The commercialized pipe size was used to reduce the overall cost of the RWH system. Figure 4 shows the schematic diagram of the RWH system.

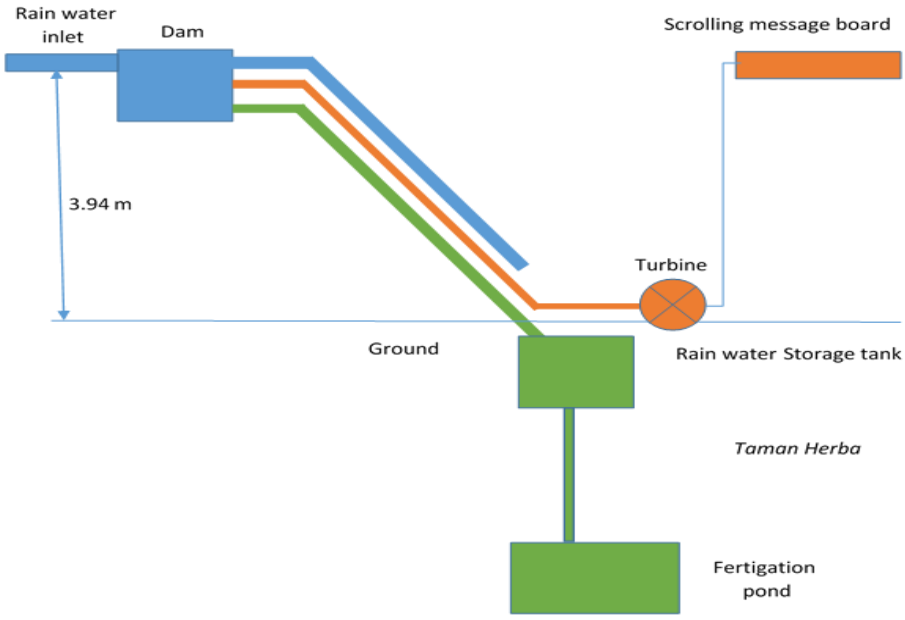

Figure 4. Schematic diagram of the RWH system.

A dam was built at the rainwater intakes on the top of the hill. The dam dimension was 1.05 m × 1.36 m × 0.6 m. The dam was located at 3.94 m above the ground (*Taman Herba*). The length of the pipe connecting the dam and the turbine was 13.9 m. The specification of the internal diameter of the pipes in RWH system is tabulated in Table 1.

Table 1. Pipe dimension of the RWH system.

Section	Internal diameter (m)
Dam to Turbine pipe 1	0.0278
Dam to Turbine pipe 2	0.0234
Dam to Normal drainage	0.096
Dam to Storage tank	0.096

The velocity of the rainwater at the inlet of the dam was calculated using Bernoulli Equation. Bernoulli Equation was applied by assuming the flow within the system is in steady state and incompressible flow. The pressure was assumed to be atmospheric pressure, and temperature of water to be at 25˚C. The Bernoulli Equation is shown in Equation (1).

$$\frac{P_1}{\rho g}+\frac{{V_1}^2}{2g}+z_1=\frac{P_2}{\rho g}+\frac{{V_2}^2}{2g}+z_2 \quad (1)$$

where P is pressure, V is the fluid velocity, and z is the vertical height.

The flowrate of the water, Q_{water} were estimated using Equation (2).

$$Q_{\text{water}} = A_2 V_2 \quad \text{and} \quad A_2 = \frac{\pi d^2}{4} \quad (2)$$

where A is the cross sectional area, and d is the diameter of pipe. As the water flow through the pipe, the water has to overcome some friction losses, h_f and minor losses, h_m. These losses which occurs throughout the pipes were calculated using Equation (3) and (4).

$$h_f = fL\frac{V_1^2}{2Dg} \quad (3)$$

$$h_m = K\frac{V_2^2}{2g} \quad (4)$$

where f is the friction factor, L is the pipe length, and K is the loss coefficient. The friction factor, f is estimated by referring to Moody chart. The value of K is tabulated in Table 2. The PVC pipe roughness for calculation was estimated to be 0.0015 m.

Table 2. Loss coefficient of various pipe components [13].

Pipe component	Loss coefficient, K
Entrance	0.5
90˚ elbow	0.3
45˚ elbow	0.4

The flow regime along the pipe were estimated using Reynolds number, Re equation as shown in Equation (5),

$$Re = \frac{\rho_{\text{water}} V_1 D}{\mu} \quad (5)$$

where ρ_{water} is the density of water, and μ is the viscosity of water. The properties of water were assumed to be constant throughout the year and taken at 25°C as shown in Table 3.

Table 3. Properties of water at 25°C.

Water density, kg/m^3	Water viscosity, kg/ms
996.95	7.252×10^{-4}

The turbine was designed and fabricated according to the Pelton wheel concept. The energy extracted from the water to turn the turbine and converted to turbine power, $P_{turbine}$ was estimated using Equation (6),

$$P_{turbine} = \xi \rho_{water} Q_{water} g z_1 \quad (6)$$

where ξ is the efficiency of the turbine. The efficiency of the turbinewas estimated to be 60%.

3. Results and discussion

The first approach of the RWH system in SMKIS was diverted and divided (2D). Theheavy rainwater in the existing drainage system was diverted into the dam. The rainwater in the dam was passed through a sequential aluminium plates of different height to filter the collected rainwater. During this process, the aluminium plates filtered the leaf while permitting the rainwater to pass through depending on the amount of the water in the dam. Filtration is sufficient for non-potable uses [14]. The rainwater in the dam was then channelled into three pipes. The first pipe was channelled into the existing draining system, whereas the second and the third pipes were distributed to a rainwater storage tank and a turbine. The separation of the rainwater flow fulfilled the second approach in this study which was collected and converted (2C). The filtered rainwater was collected in the water storage and becomes water supply to the fertigation pond and plant watering in *Taman Herba*. The water from the final pipe was supplied to a turbine and converted into energy.

3.1. Flow rates

The primary function of the dam is to reduce the rain flow rate from the upper hillside before the water is flowing into the existing drainage system, the turbine and the rainwater storage tanks. The length and diameters of all the pipes of the RWH system tabulated in Table 1 were used for flowrate and turbine power calculation. The velocity and flowrate of the turbine, the normal drainage and the rainwater storage tank were calculated using Equation (1) and (2) are tabulated in Table 4.

The results shown that the divert and divide approach for a RWH system significantly reduced the reliance on the drainage system at the hillsides of the *SMKIS* by 50.9%. Only 49.1% of the rainwater passed through the existing drainage system and no overflow was observed during heavy rain. The

49.1% of the excessive rainwater was stored in the dam and linked to the main rainwater storage at the bottom of the hill and 1.8% of the rainwater was supplied to the turbine. The RWH system successfully minimised the likelihood of flood on the school compound and overflown the drainage system in the hillsides.

Table 4. Flowrate of RWH system.

Section	Velocity, V (m/s)	Flowrate, Q (m^3/s)	Percentage (%)
Dam to Turbine	3.5	1.6×10^{-3}	1.8
Dam to Normal drainage	5.2	4.5×10^{-2}	49.1
Dam to Storage tank	5.2	4.5×10^{-2}	49.1

3.2. Experiential learning platforms

The second approach of collect and convert successfully installed in the *SMKIS*. A fertigation pond was built and a turbine was designed as a feasible energy source for the scrolling message board at *Taman Herba*. The fertigation pond is the natural habitats for fresh water fish. The main storage tank was put before the fertigation pond to store for other usage like plant watering. The turbine and the fertigation pond are shown in Figure 5.

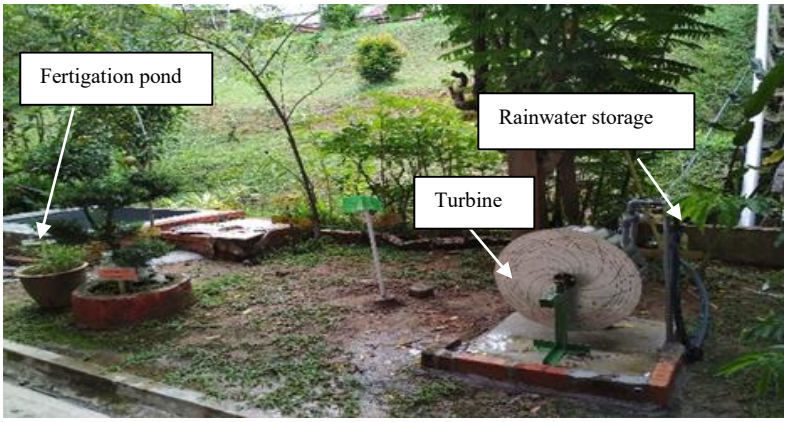

Figure 5. Experiential learning platform at *Taman Herba.*

The schematic energy harvesting system for the scrolling board is illustrated in Figure 6. The dam stored enough potential energy which was then being extracted by a rotating turbine to convert into kinetic energy. A generator converted the kinetic energy to electrical power that was used to operate a scrolling message at *Taman Herba*. Equation (1) to (6) were used to calculate the power generation by the turbine. The losses, friction factor and Reynold number are presented in Table 5. The power generated by the turbine was 26.6 W.

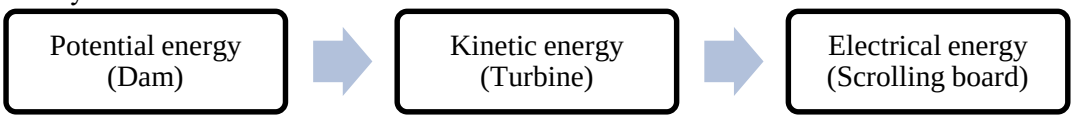

Figure 6. Energy harvesting system for scrolling board.

Table 5. Calculated parameters used to determine the power turbine.

Parameter	Value
Friction losses, h_f	4.47 m
Minor losses, h_m	1.02 m
Friction factor	0.0178
Reynolds number	104328
Turbine power	26.6 W

The harvested rainwater can be used for watering the plants at *Taman Herba*. The turbine and the fertigation pond become the beneficial site for the students at *SMKIS* to learn on energy generation and freshwater habitats at the same time improving the decorative landscape at the school.

4. Conclusion

This study developed the RWH system for *SMKIS* which consisted of a dam, a filter and a storage tank. The RWH system was connected to a turbine and a fertigation pond to expose the students to experiential learning. The dam successfully reduced the flow rate in the existing drainage system by 50.9% and streamed 49.1% of the harvested rainwater to storage tank and subsequently to the fertigation pond at *Taman Herba*. Another 1.8% of the harvested rainwater generated 26.6 W power for the scrolling and message board. This work successfully reduced heavy rainwater flow rate at the existing drainage system, and at the same time beneficial as water saving, plant watering, energy generation and sustaining *SMKIS* landscape decoration.

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