DEVELOPMENT OF PV CATCHMENT MECHANISM FOR RAINWATER HARVESTING IN MALAYSIA

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Abstract- This study demonstrates a rainwater harvesting approach via Solar Photovoltaic (PV) array catchment embedded with a simple Polyvinyl Chloride (PVC) guttering mechanism as the collective device. The issue of freshwater resources being continuously contaminated and polluted deemed to create water supply shortages. In urban areas where working population dominates, demands for freshwater supply increases rapidly over the years which lowers the government's capability to supply and keeping in pace with the basic need in the near future. The Rainwater Harvesting PV (RWHPV) collector apart from the normal function of electricity generation is suggested as means of new attempts for resource recovery furthermore neglecting waste of water and flooding. The system comprises main component of 1kWp fixed flat monocrystalline PV modules of 3.6m (Length) by 2.4m (Width) constructed at 7.6^{o} tilt angle facing 160^{o} South based on a fixed high quality steel frame structure. The RWHPV system are located at Universiti Putra Malaysia PV pilot plant in Serdang district of Selangor which has a good rainfall collection throughout the year. The sample rainwater from RWHPV are stored in a container for detail analysis of water quality, nutrient, pH level, and heavy metal contents.

Keywords- PV Catchment, Rainwater harvesting, Tropics, water nutrient, pH level

I. INTRODUCTION

Since the past decades, fresh water supply has been the crucial resources for all living things especially human being on the planet earth. Malaysia a tropical climate country has enormously been received 3,000 mm/ average annum of rainfall which contributed to approximately 900 billion cubic meter of water supply. Freshwater ecosystem originally derived from the rainfall thru forested wetlands and water bodies are currently at risks largely due to environmental pollution and rural development. The WWF-Malaysia's Freshwater Programme has proposed an outreach approach comprising the following three areas:

1. Conserving river basins – maintenance and restoration of freshwater habitats and ecological processes within key river basins using approaches such Integrated River Basin Management (IRBM);
2. Sustainable water use – focuses on sustainable water use policies and practices that contribute to freshwater habitat conservation using approaches such as Integrated Water Resources Management (IWRM); and
3. Conserving freshwater habitats – focuses on improved protection and management of priority freshwater habitats

Source from http://www.wwf.org.my

In urban areas where working population dominates, demands for freshwater supply increases rapidly over the years which lowers the government's capability to supply and keeping in pace with the basic need in the near future. Jamaluddin et al. (Suhaila, Jemain, Hamdan, & Wan Zin, 2011) explains that Peninsular Malaysia (as shown in Figure 1) is situated in the tropics between 1° and 7° north of the equator and at eastern longitude from 100° to 103°E which is very much influenced by the monsoons. The southwest monsoon (SWM) occurs from May to August while the northeast monsoon (NEM) occurs from November to February.

The period of the SWM is a drier period for the whole country, while during the NEM, the eastern areas of Peninsular Malaysia receive heavier rains than the other parts of the country. Heavy rainfalls are also expected during the two inter-monsoons: March–April and September–October. (Mohtar, Yahaya, & Ahmad, 2015; Varikoden, Preethi, Samah, & Babu, 2011)

A comprehensive study on Tropical Rainfall diurnal variation in the spatial domain of Peninsular Malaysia for a 10 years period (1999 – 2008) are conducted by Hamza et al. (Varikoden et al., 2011) using the rain rate from Tropical Rainfall Measuring Mission (TRMM). The group classified the rain intensity (R in mm/h) into low ($R < 4$), moderate ($4 < R < 8$), high ($8 < R < 12$) and very high ($R > 12$) and concludes some important findings on Rainfall occurrences based on several class intensity covering Malaysia nominal 4 season monsoon

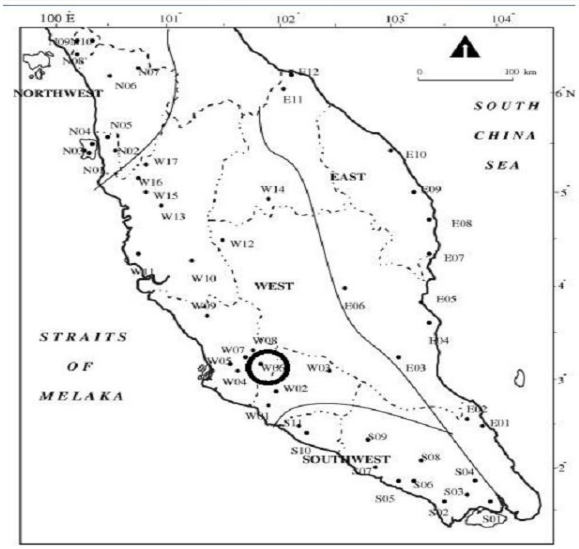


Figure 1: Topography of Peninsular Malaysia with circled sample site for RWH project in Serdang, Selangor

- The maximum number of occurrences are more observed from 1700 h to 2000 h with a frequency of more than 25% with the maximum number of occurrences are observed during the early northeast monsoon season and are followed by the southwest monsoon season
- During the northeast monsoon period, the western regions (especially in Klang Valley area), receives very high intensity rainfall (>12 mm/h) leading to flash flood. The rainfall contributes more than 30% of the seasonal rainfall, indicating high amount of rainfall from a short interval of time potentially leading to land slides and flash floods

A recent flood epic in Serdang district within 5 km radius from the project site occurs in April 2014. Heavy rains which started at 3pm causes water overflow onto the roadside causing massive traffic disorder as shown in Figure 2.



Figure 2: Heavy rains in Serdang District causes drainage overflow. Source from http://www.met.gov.my/

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams.

The techniques usually found in Asia and Africa arise from practices employed by ancient civilizations within these regions and still serve as a major source of drinking water supply in rural areas (Behzadian, Kapelan, & Morley, 2014; Nicholson, Clark, Long, Spicher, & Steele, 2009).

II. METHODOLOGY

The Rainwater Harvesting PV (RWHPV) collector apart from the normal function of electricity generation is suggested as means of new attempts for resource recovery, furthermore neglecting waste of water and flooding. The system comprises main component of 1kWp Fixed Flat (FF) monocrystalline PV modules of 3.6m (Length) by 2.4m (Width) constructed at 7.6^0 tilt angle facing 160^0 South based on a fixed high quality steel frame structure as shown in Figure 3. (Ya'acob, Hizam, & Radzi, 2014)



Figure 3: 1 kWp Fixed Flat Photovoltaic System at UPM site

The RWHPV system which is a modified version of the FF PV are located at Universiti Putra Malaysia PV pilot plant in Serdang district of Selangor which has a good rainfall collection throughout the year. A simple modification of PV skirting system, water storage and silicon bonding between each PV module are shown in Figure 4.



Figure 4: Development of RWHPV using PV skirting, water storage and silicon bonding for collecting rainwater.

III. RESULTS AND DISCUSSION

The harvested Rainwater sample has been collected during rainy days using RWHPV system for detail analysis based on standard method for examination of water and wastewater (APHA: American Public Health Association). The results are segregated in three category namely RW Nutrient, Quality and Heavy Metals Analysis as folllows:

Rainwater Nutrient Analysis
Total Nitrogen (1.3 mg/L), Phosphorus (0.17 mg/L), Potassium (0.46 mg/L) , Calcium (3.2 mg/L), Magnesium (0.33 mg/L) and Sodium (0.83 mg/L).

Rainwater Quality Analysis
pH level (5.1), Fluoride (1.0 mg/L), Chloride (3.7 mg/L), Ammonium (0.82 mg/L), Nitrate (1.4 mg/L) , Sulphate (8.0 mg/L)

Rainwater Heavy Metal Analysis
Heavy Metal Part : Iron (Not Detected) , Zinc (0.11 mg/L), Mercury (Not Detected), Copper (1.0 mg/L), Manganese (Not Detected), Nickel (Not Detected) and Lead (Not Detected)

Based on the rainwater analysis, most of the components found in the rainwater are macro and micronutrients for the plantation. Even though the values of the nutrients are not much, these can be as a replenishment for the soil enrichment and nutrients uptake by the plantation if the rainwater collected is used for irrigation water or even just as watering the plants.

The primary macronutrients are nitrogen, phosphorus and potassium, whereas calcium, magnesium and sulphur are secondary macronutrients. Nitrogen is essential for plant growth and necessary for chlorophyll synthesis. The plants take up most of the nitrogen as ammonium or nitrate. Phosphorous is needed in promoting root development and early seedling growth whereas potassium enhances many enzyme actions in aiding photosynthesis and food formation. Calcium is required to stimulate root and leaf development and indirectly improving root growth conditions and stimulating microbial activity whereas magnesium is acted as a phosphorous carrier in plants for better root formation and better nutrient and water efficiency in plants as well as to capture the sun's energy for growth and production through photosynthesis. Sulphur is needed to aid in seed production as well as important in photosynthesis and for synthesis of certain amino acids and proteins. Sulphur is absorbed primarily as sulphate (Jampeetong, Konnerup, Piwpuan, & Brix, 2013; Vimala, Mohd. Yusoff, Mohamed Senawi, Abdul Ghani, & Ahmad Shokri, 2002; Yadvinder-Singh, Bijay-Singh, & Timsina).
The heavy metal analysis is done to detect the micronutrients for the plantation. Though only two are detected, these micronutrients may aid synthesis of plant-growth substances and enzyme systems and is essential for promoting certain metabolic reactions which are very critical in the early growth stages (Kadhum, Ishak, Zulkifli, & Hashim, 2015). Chloride is the most recent addition to the list of micronutrients where it is an important element for growth and health of the plant.
The drawback of this rainwater sample however, is the acidic condition of the water which may damage the cell growth of the plants. In addition, the tissue of the plants especially on the tips of leaves may be affected to the fluoride toxicity.

CONCLUSION

In summary, the rainwater harvesting using RWHPV system based on modified fixed flat solar photovoltaic generators can be a suitable device in

collecting rain water and gives beneficial nutrients for plant growth when supplying the water for irrigation or plant watering. Minor improvement is needed to reduce the acidity of the water as well as fluoride toxicity.

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