TECHNO-ECONOMICS OF RAINWATER HARVESTING TECHNOLOGY FOR DOMESTIC USAGE AND COOLING

ABDURAHIM ALMABRUK SHATEWI

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DEDICATION

Who Always Pushes Me Forward ***My Father.***

Who Takes Care of Me Growing Up ***My Mother.***

Whom Take My Success As Guide For Their Success ***My Brothers.***

Who Smiles For My Smile ***My Wife.***

Who Gave Me the Knowledge ***My Lecturers.***

Whom Joined Me This Way ***My Classmates.***

Who Ever Supported Me To Accumulate This Research. . ! ! !

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ABSTRAK

Kajian yang telah dijalankan ini adalah berkenaan penggunaan air hujan sebagai bekalan air tambahan bagi kawasan penempatan. Kajian ini menerangkan penggunaan sistem pengumpulan air hujan yang boleh diaplikasikan bagi kawasan penempatan dengan tambahan sistem penyejuk pasif (*passive cooling system*). Analisa telah dijalankan dengan membina pengkalan data air hujan bagi kawasan kajian tersebut. Penggunaan air bulanan bagi isirumah telah dianggarkan bagi mengenal pasti kapasiti/ukuran untuk sistem pengumpulan air hujan tersebut. Analisa yang telah dijalankan ini seterusnya boleh digunakan bagi mendapatkan kapasiti optima sistem pengumpulan air hujan itu. Satu sistem penyejuk pasif yang menggunakan air hujan sebagai agen penyejuk bertindak untuk mengurangkan suhu dalaman. Sistem penyejuk pasif ini akan menyumbang kepada pengurangan suhu dalaman dan kapasiti penyejukan sistem penghawa dingin yang seterusnya mengurangkan penggunaan tenaga elektrik secara keseluruhannya. Satu analisa juga akan dijalankan keatas sistem *prototype* bagi mendapatkan kos sebenar dari segi ekonomi yang boleh diguna pakai bagi kawasan penempatan. Kajian dari segi ekonomi ini juga merangkumi penjimatan untuk bil air dan elektrik. Penjimatan ini seterusnya boleh digunakan bagi mendapatkan tempoh bayaran balik yang mudah bagi pelaburan permulaan untuk membina sistem tersebut. Dari kajian ini kita boleh membuat perbandingan dan selanjutnya dapat menentukan kebolehupayaan untuk menjalankan kajian ini dari segi penjimatan kewangan dan aplikasi jangka masa panjang bagi sumber air.

ABSTRACT

The study on the use of rainwater as a supplementary water supply for residential dwellings was conducted. This study elaborates rainwater harvesting systems that can be applied at residential dwellings with an additional passive cooling system. The analysis was conducted by building a database of rainfall in the test area. The monthly household use was estimated to determine the sizing for the rainwater harvesting system. This analysis was then used to determine the optimum size of the overall rainwater harvesting system. A passive cooling system using rainwater as the cooling agent was designed to reduce indoor temperatures. This passive cooling would contribute to the reduction of the indoor temperatures and the cooling load of the air conditioning system, which will in turn, reduces electrical energy consumption. A proposed cost analysis will be conducted on the prototype system to determine its economic feasibility to be applied at residential dwellings. This economic review will also included the savings from water and electricity bills. These savings will be used to determine the simple payback period on the initial investment to build the systems. From the study we can make some comparisons and conclude the viability of implementing the system in terms of monetary savings and the long term application of a sustainable and renewable source of water.

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LIST OF SYMBOLS

A_1	-	Cross-section area of downspouts pipe (1)
A_2	-	Cross-section area of downspouts pipe (2)
A_3	-	Cross-section area of main downspouts pipe
A_{roof}	-	Catchment surface footprint area
COP	-	Air-condition unit coefficient of performance
CR	-	Run of coefficients
$D_{(0.85)}$	-	The deference (WT - $W_{(0.85)}$)
$D_{(0.95)}$	-	The deference (WT - $W_{(0.95)}$)
H	-	Water level height in the tank
H	-	Pump head
HP	-	Pump Hours power
L_{max}	-	Maximum pipe length
L_{min}	-	Minimum pipe length
m_1	-	Water mass flow rate through downspouts (1)
m_2	-	Water mass flow rate through downspouts (2)
m_3	-	Water mass flow rate through main downspouts
Q	-	Pump Water flow
Q	-	Heat transfer rate

$Q_{cooling}$	-	The removed heat by air-condition unit
R_0	-	Overall thermal resistance
TD	-	Temperature difference
T_H	-	High temperature (roof)
T_L	-	Low temperature (room)
U	-	Overall heat transfer coefficient
V	-	Water volume (liter)
V1	-	Tank Rectangular part volume
V2	-	Tank parabolic part volume
$W_{(0.85)}$	-	Calculated Harvested rainwater when (CR = 0.85)
$W_{(0.95)}$	-	Calculated Harvested rainwater when (CR = 0.95)
$W_{cooling}$	-	The energy consumption by the air-condition unit
$W_{Harvested}$	-	Harvested rainwater in liters
$W_{Rainfall}$	-	Rainfall amount in mm
WT	-	Harvested rainwater amount in the tank
Y	-	Parabolic width on the water level

CHAPTER 1

INTRODUCTION

1.1 Introduction

The never-ending exchange of water from the atmosphere to land and the oceans and back again is known as the hydrologic cycle. All forms of precipitation (hail, rain, sleet, and snow), and consequently all movement of water in nature, forms part of this cycle. Precipitation stored in streams, lakes and in soil evaporates while water stored in plants transpires to store of water in the atmosphere. When the atmospheric conditions reach a level of super saturation, a stat achieved as a result of increased humidity combined with changes in temperature and pressure, this water is released in the form of rain, sleet, snow or hail, which falls as a result of the force of gravity to the earth. The cycle continues, and results in shifting water from sea level all the way into the mountains and back into rivers, lakes and the sea etc.

Rainwater harvesting is the collection and storage of rainwater from roofs or catchment surface for future use. The collected water is stored in tanks for future use. The usage way (water distribution) is depending on the rainwater applications. Did you know that although 70% of the earth is covered with water, only 3% of this water is fresh water? Out of this, 2% is locked in the form of ice, and it is only the balance 1% of water that recycles through the evaporation, condensation cycle, that flows into the rivers and lakes, to be used mankind [1]. So, the aim of this technique is to collect fresh water (rainwater) to improve the mankind uses especially in dry regions. Rainwater is valued for its purity and softness. It has a nearly neutral pH, and is free from disinfection by-products, salts, minerals, and other natural and man-made contaminants accept the development area (acid rain). If the rain fall persists for long time only the fist part of rain will be bulleted.

1.1.1 Brief history

Collecting and storing rainwater is not a new idea. While the origin of rainwater catchments systems are not known precisely, historical evidence suggests structures for holding runoff water date back to the third millennium BC[2]. Historical structures range from saucer like ground catchments and below ground cisterns to above ground rooftop runoff storage tanks, have been found in numerous locations in Middle Eastern, Asian and Mediterranean countries as Negev desert, , India, Greece, Italy, Egypt, Turkey and China. It is found in Mexico, Taxes and Arizona as well. Historically, harvested rainwater provided water for daily life use as drinking, cooking, washing and landscape watering. Once urban areas started to develop, centralized water supply systems replaced the need to harvest water [3].

1.1.2 Cooling energy consumption

The main contributor to increasing atmospheric carbon dioxide (CO_2) concentration is the combustion of fossil fuels from electricity generation, commercial and domestic uses. The demand for energy is expected to grow rapidly in developed countries as well as in the developing countries as they attempt to obtain a higher standard living. This increase energy demand and consequently increase carbon dioxide concentration in the atmosphere.

As energy costs rise, and the public becomes more aware of the environmental damage arising from current energy use patterns. In most of hot just as much energy, if not more, may be used for cooling to achieve the thermal comfort. Refrigeration and air conditioning systems have a major impact on energy demand with roughly 30% of total energy consumption in the world [4]. With fossil fuels fast depleting, it is imperative to look for refrigeration systems that require less high-grade energy for their operation. A minimum amount of energy should be use for cooling.

Typically, air-conditioning accounts for 60% of electricity consumption in commercial buildings in the hot and humid Southeast Asian Region [5]. Residential households in urban and suburban areas use air-conditioning for thermal comfort increasingly. Typically, one air-conditioner will be initially installed in the main bedroom of a house. With increase in disposable income, a household would add second, third and possibly more units to other bedrooms and common rooms. There is increasing penetration of air-conditioning, both in terms of number of households and in terms of number of air-conditioners per households, that the air-conditioning industry reports increasing annual number of units sold that approaches 5% of the number of households in Malaysia and Thailand. When air-conditioning is used, it contributes 70% of electricity consumption in a household [5]. Alternative methods, using passive cooling techniques, can assist in reducing the conventional energy consumption in buildings. Researchers have shown that about 50% of the heat gains for a single-story building come through the roof [6]. The conventional approaches to reduce heat flux through the roof into a building include increasing thickness of the roof, providing insulation and false ceilings, shading the roof and using reflective finish or coating. In hot dry areas, however, this can be achieved by an open pond, thin water film and spraying water on the roof [7]. The passive cooling is a feasible technology that can reduce mechanical cooling and energy requirement in air conditioning application that will effect to decrease emissions from electricity generation.

1.2 Problem Statement

Malaysia is tropical region (hot, humidity and raining weather). Rainwater harvesting can be supplementary water source for residential dwelling. The study will predicts how much rain water can be harvested. Also it will show, whether the harvested rainwater will be partial coverage of the water requirements of daily usage (drinking, cooking, shower, washing, toilet flush, washing front yard, watering plants and washing cars …ect), during whole of the year, or it will be full coverage. The harvesting rainwater can be used for passive cooling technique (spry water on the roof) to reach the thermal comfort.

1.3 Aim and Objectives of Study

An overall goal of this study is to meet water demand for residential dwelling. The study will show how much the harvested rain water well reduces the usage of the public water supply. In other wards, how much the water bill can be reduced? On the other hand, by using the harvesting rainwater for passive cooling technique (spry water on the roof), well decrease the cooling electrical energy (air-condition) to reach the thermal comfort.

The objectives of this study by using case study of rainwater harvesting system and passive cooling technique (spray water on the roof) as the following:

1. Fundamental study of rainwater systems used for rain harvesting.

2. To Acquit observables facts in implementing rainwater harvesting techniques with residential dwellings.

3- To find out the performance passive cooling technique (spraying water on the roof).

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