Solar water heating by using polyethylene tetraphalate bottle

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***Abstract*:- A solar water heater prototype was constructed using polyethylene terephthalate bottles to determine its feasibility as a component of the average household in rural areas in Sangola. The main problem now associated with the world is, lack of clean and fresh water. Nearly 1.2 billion people lack access to safe drinking water and 2.6 billion have little or no sanitation at all. solar disinfection is a simple method of water treatment that consists of exposing a bottle of biologically contaminated water to direct sunlight, allowing UV component of the light to energize reactions (both optically and thermally) in the water that kill or inactive microorganisms (microbial disinfection). PET (Polyethylene terephthalate) is commonly used in the form of bottles, fibers and films. PET bottles can be reused as solar disinfectant de-polymerized products; solar water heater etc. PET bottle recycling is more practical than many other plastic materials. The primary reason is that plastic carbonated soft drink bottles and water bottles are almost exclusively consists of only PET and it is easy to recycle.PET is currently the most investigated one due to its low cost, transparency, lightweight, flexibility, chemical resistance and low thermal expansion coefficient**

***Keywords*: PET Bottle, tubes, solar energy, law of bumbarding**

INTRODUCTION

1. 1 Water access and wood consumption

In the rural areas 3 out of 4 people are poor. Nevertheless, 89% of the population in rural areas have water access (The World Bank, 2015) and nine out of ten people depend on wood energy 75% collects wood and 25% buys it .

It is estimated that Guatemala losses between 50 and 70 thousand hectares per year; 60% of its primary energy consumption comes from wood. It is clear that, like in any other developing country, wood represents the only available and affordable source of energy for most households. In fact, more than two billion people depend on wood for cooking and heating .

1.2 Water heating and recycling of polyethylene tetrephthalate bottles

Despite the popularity of wood as an energy source for cooking and heating, its use might have harmful effects on health when rudimentary stoves are used as the burning means; such devices allow the smoke to pollute the household air with ashes. As a health–friendly alternative to rudimentary stoves, improved stoves (that block smoke leakage inside the house) have been developed and promoted since the early 1980s

. Aside from health benefits, improved stoves have the advantage of higher efficiency. Thus, its implementation also helps reduce wood consumption or deforestation.
Another potentially cheap source of energy that can be used in rural areas is solar energy for water heating.

- Certain solar water heaters SWHs made of cheap and recyclable materials (such as polyethylene terephthalates PET - thermoplastic polymer- bottles) can heat the water up to 52 ° C
- Hot water in rural households can be used for cooking, sanitizing and for hot showers
- As a complement to improved wood stoves, a solar water contributes keeps the household from using wood, therefore, reducing health risks and deforestation
- The collection of PET bottles for the construction of SWHs can be added to recycling programs One the advantages of collecting PET bottles for SWHs is to keep them out of landfills, protecting the environment; PET bottles take about 450 years to decompose . Even in developed countries like the U.S, the recycling rate of PET bottles is only 31% (each year 1.5 billion PET bottles and containers are recovered in the U.S for recycling). In Mexico (the second largest PET bottle consumer after the U.S), the third largest expense for the typical household, after tortillas and milk are sodas .As for solar water heating, with the goal of reducing hydrocarbon fuels, Mexico already implemented a program about the installation of 1.8 million square meters of SWHs by 2012 . Although the SWHs are not necessarily targeted to rural areas, the Mexican government seeks to reduce the consumption of natural gas with solar energy., it is estimated that 42 thousand tones of PET bottles are recovered each year for recycling .With the exception of programs that promote the use of various models of improved stoves , programs supporting the use of other means (besides wood) for water heating in the countryside, such as SWHs are either scarce or nonexistent. Regardless, there already have been proposals of cheap solar water heaters for rural areas

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BASICS OF SOLAR WATER HEATING

One of the simplest designs for a SWH corresponds to the *thermo siphon SWH*, which is the case for the solar water heater discussed in this paper. A general diagram for the thermo siphon SWH is shown in Figure 2. Water is heated directly by solar radiation by circulating through the collector. The cycle starts as the sun comes out and heats the water inside the collector; hot water rises -a convection current- and reaches the storage tank which is located above the collector (the top of the storage tank is connected to the top of the collector). Meanwhile, water at lower temperature inside the storage tank, flows to the collector (the bottom of the storage tank is connected to the bottom of the collector); water at lower temperature has higher density, causing it to *sink*, leaving the storage tank with water of lesser density: hot water. Thus, a thermo siphon circulation is triggered. Note that such a system does not require the use of pumps; only natural forces are involved.

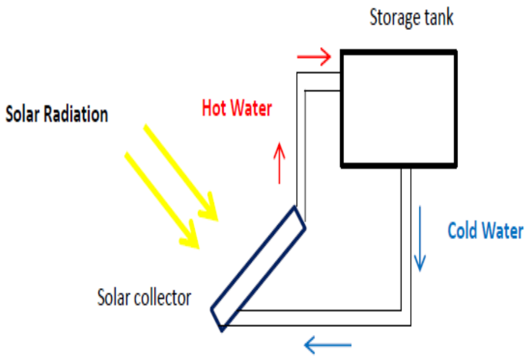
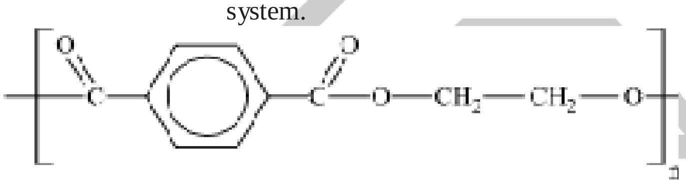


Fig 2.1 Schematic diagram for a thermo siphon solar water heating system.



1.3 Solar radiation

All things considered, there's a clear opportunity to exploit solar energy in Guatemala: many regions experience at least 6 hours of solar radiation per day at 1kW/m2 (see Figure 1). In fact, the largest solar park in Central America, of 5 MW, located in the south east of Guatemala, will be naugurate din May 2015

It is widely known that a thermo siphon solar water heater has the following advantages:

- Simple
- Electricity free
- Does not need external pumps

However, the main disadvantages of a TSWH involve lack of plumbing knowledge and skills. Wrong election of tubing may allow air pockets to block the water flow. Besides, if the pipes that connect the collector to the storage tank are not steep enough, the thermo siphon effect might not occur. That without mentioning eventual leaks due to bad connections, poor insulation of the tank etc. In short, the supervision of a professional is recommended in the construction and installation of a SWH. Thus, if the plumbing is appropriate, unobstructed water circulation will happen. The thermo siphon will depend then, on how well solar energy is absorbed by the water in the collector, actually at the exact part where radiation is to be absorbed, which is usually called *receiver* (usually a black surface) The energy balance for a solar collector receiver –the main component of the collector- is described by ,

$$\dot{Q}_{useful} = \dot{E}_{opitical} - \dot{Q}_{loss} \quad (1)$$

where

$\dot{Q}_{useful}$= rate of useful energy from the receiver
$\dot{E}_{optical}$ = rate of optical radiation incident on receiver
$\dot{Q}_{loss}$ = rate of thermal energy loss from the receiver

Note that for conventional receivers the incident radiation corresponds to short wavelength, due to the fact that glass - usually the transparent cover of the receiver, which is encapsulated - reflects most infrared light. As for the useful energy, it can be expressed as the rate of heat transfer to the fluid passing through the receiver

$$\dot{Q}_{useful} = \dot{m}\, c_p \,(Tout - Tin)$$

where the following quantities refer to the heat transfer fluid:

ṁ = mass flow rate of fluid
cp = specific heat of fluid
Tout = temperature of fluid leaving the absorber
Tin = temperature of fluid entering the absorber

Now, when $E_{optical}$ and $\dot{Q}_{loss}$ are expressed in terms of physical properties, and $\dot{Q}_{loss}$ is written as a sum of the loss mechanisms [18] (convection, radiation and conduction) we get from (1) and (2)

$$\dot{Q}_{useful} = \dot{m}\, cp\,(Tout - Tin) = \tau\alpha\, Ia\, Aa - Ar\,[\,h'\,(Tr - Ta) + \varepsilon\sigma\,(T4r - T4a)]$$

where

the factors , both of them less than 1, from the first term are

τ = transmittance of transparent cover
α = absorptance at the surface of receiver

The transmittance τ equals the fraction of solar radiation that passes through the transparent cover, above the receiver. Note that glass, for example, allows most visible light to pass, while reflecting most of the infrared part of the spectrum. Plastics, in contrast, u is the fraction of absorbed radiation, in this case, by the receiver surface (usually of black colour, for optimal absorption).

The two factors above are related to the incoming solar radiation in the first term in (1); where

Ia = solar irradiance entering the collector aperture
Aa = area of the collector

Actually, the factors of the first term, transmittance and absorptance, represent losses, as radiation travels from the collector aperture (where glass or any transparent material is placed as a cover) to the receiver.

The processes of these losses depend specifically on the design of a particular collector and happen due to the physical limitations of materials and imperfections in geometry.

Belonging to the second term of (1) we find the quantities from $\dot{Q}_{loss}$ where Ar = surface area of receiver, then the first part of the second term, combines convection and conduction, so that:

h´ = combined convection and conduction coefficient
Tr = average temperature of receiver

Ta = average temperature of ambient air
It is important to note that the main source of heat loss for a solar collector is the convective one ,therefore, modern solar collectors use vacuum glass tubes with pipes inside. Since conduction loss is commonly small compared to convection loss, it is usually combined with the convection loss factors for general approaches.
The second part in the second term represents the loss of energy by radiation, where
ε = thermal emmittance of the receiver surface
σ = the Stefan-Boltzmann constant
In general, radiation and conduction losses are comparable for collectors when the operating temperatures are nearly ambient. Thermal emmittance and absorptance are parameters that the manufacturer can easily control when appropriate coatings are chosen .

ACTUAL WORK CARRIED OUT FOR THE SAME

The pet bottle SWH

The PET bottle solar collector was invented in 2002 by a Brazilian retired mechanical engineer José Alano. For the invention, Alano was granted the “2004 Ecology Prize for NGOs” in Brazil
By 2008, six thousand units of Alano’s ecological SWH had already been built. The largest version -that uses 1,800 PET bottles- was inaugurated that same year in the Brazilian town of Palmas .

SWH uses PET bottles to substitute glass (as in conventional SWHs) as the means to create the greenhouse effect inside the collector – the phenomenon that causes the water inside the pipes to heat up. However, as mentioned earlier, plastics do not reflect most infrared radiation. Measurements in the range of 360 to 1040 nm wavelength (which corresponds to significant portion of the solar radiation spectrum at sea level) have shown that colourless PET have a high 88% - 90% light transmission .
Such property may reduce the greenhouse effect inside the bottles, and ultimately, the efficiency of the system.

RESULT

The seven individual samples are taken and the readings were taken for every one hour. The ambient and water temperature of the each sample is noted. The Solar Insulations is taken via the pyranometer. ΔT was obtained by subtracting water temperature with ambient temperature. From the value of water temperature maximum obtained for PET bottle at the range of 52˚C because the absorbs solar radiation via the water so that its water temperature is high comparing the other samples. PET bottle the heat observed on the outer surface of the bottle. Comparing the Pure PET reaches the maximum water temperature shows the water temperature versus with time. Maximum value of water temperature of each sample is given by,

CONCLUSION

The PET SWH heats up the water from ambient temperatures of 30 °C to range 48-52^{o}C. The efficiency is comparable to the one found in literature. It is clear, however, that this design of PET SWH will need the elaboration of a thorough physical model to determine its maximum potential, that is, its maximum efficiency by using low cost and easy to find materials.

Although the current cost of the prototype of USD 221 can easily be reduced to USD 127, by
Regardless, Alamo's SWH heats up the water up to 38 °C in the winter (ambient temperatures of 13°C to 16°C and in summer up to 50 °C (ambient temperatures of 22 °C to 25 °C . A remarkable efficiency despite the PET bottles optical limitations. On another hand, the durability of PET bottles allows them to be used in the open air for up to 10 years without important changes in strength and lighting properties

The Prototype

Ever since the PET bottle SWH from José Alano was popularized, many versions of his invention were created. The prototype discussed in this paper was designed based on those versions. For instance: instead of using black painted tetrapack cartons as heating surfaces inside the bottles, the bottom of the bottles was painted black with plastic cement and -as a receiver-

Table 4.1 temp of water

Time	Inlet water temp IN ^{O}C	Outlet water temp IN ^{O}C
AT 10 AM	30^{O}C	45^{O}C
AT 11AM	30^{O}C	48^{O}C
AT 12 NOON	30 ^{O}C	58 ^{O}C
AT 1 PM	30 ^{O}C	61 ^{O}C
AT 2 PM	30 ^{O}C	52 ^{O}C
AT 3 PM	30 ^{O}C	48 ^{O}C
AT 4 PM	30^{O}C	45^{O}C

replacing the bases of the collector and the tank with cheaper materials, its cost makes it available only for the middle class as a DIY project, that requires basic plumbing knowledge and skills. In such case, further studies are needed to determine how much electricity is saved when a standard (yet to be determined) PET SWH is used to find out the payback period.

Due to its cost and the lack of government subsidy for green technologies in households, the PET solar water heater is not feasible to the low income family in rural areas. Its affordability for that market, depends, then, on the support international programs, such as UNDP, or on the creation of a disruptive business model such as Quetsol.

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he main advantage of the PET SWH over other low cost systems is the way it addresses environmental protection and health issues

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