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Solar Water Purifier

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Abstract— ***Carbon filters are very effective at removing chlorine, benzene, radon, solvents trihalomethane compounds, volatile organic chemicals such as pesticides and herbicides and hundreds of other man-made chemicals that may come into contact with tap water as it proceeds through the system. In addition, filters remove bad tastes and odours from the water [NDSU, WQ-1029] [4]. After this initial filtration by carbon filter, water is then passed to evacuated vacuum tubes for remaining purification. A parabolic trough is a type of solar thermal collector that is straight in one dimension (Z-axis) and curved as a parabola in the other two (X and Y-axis), lined with a polished mirror like finish metal. The energy of sunlight which enters the collector parallel to its plane of symmetry is focused along the focal line where the vacuum tube is placed. The vacuum that surrounds the outside of the tube greatly reduces convectionand conduction heat loss, therefore achieving greater efficiency than flat-plate collectors.***

Keywords— ***Solar, Water Purifier, Thermal distillation, carbon filter, parabolic dish***

I. INTRODUCTION

Solar water purification includes two aspects; first aspect is sediment removal using carbon filter then, pathogen elimination in the manifold due to heat generated by natural convection due to parabolic trough. Initial filtration is carried by carbon a filter. Carbons filtration is a method of filtering that uses a bed of activated carbon to remove contaminants and impurities using chemical adsorption. Carbon filters are very effective at removing chlorine, benzene, radon, solvents trihalomethane compounds, volatile organic chemicals such as pesticides and herbicides and hundreds of other man-made chemicals that may come into contact with tap water as it proceeds through the system. In addition, filters remove bad tastes and odours from the water [NDSU, WQ-1029] [4]. After this initial filtration by carbon filter, water is then passed to evacuated vacuum tubes for remaining purification. A parabolic trough is a type of solar thermal collector that is straight in one dimension (Z-axis) and curved as a parabola in the other two (X and Y-axis), lined with a polished mirror like finish metal. The energy of sunlight which enters the collector parallel to its plane of symmetry is focused along the focal line where the vacuum tube is placed. The vacuum that surrounds the outside of the tube greatly reduces convectionand conduction heat loss, therefore achieving greater efficiency than flat-plate collectors. Thus with higher concentration ratio and with appropriate acceptance angle, the parabolic trough will concentrate more thermal radiation on the tube where it will absorb heat and will transmit it to the water inside, to raise its temperature to 80°C and more(i.e.to the pasteurization temperature of water) to kill or deactivate all classes of pathogens including protozoan cysts that have shown resistance to chemical disinfection and viruses that are too small to be mechanically removed by microfiltration. As the water heats due to radiation from the sun, the increased temperature will kill or inactivate an important part of commonly waterborne pathogenic bacteria, viruses, helminthes, and protozoa at a temperature between65° and 75°C (i.e.149-167°F) (Backcountry Drinking Water)[6],thus making water drinkable.

II. AIM AND OBJECTIVES

- The aim of our project is to harness solar thermal energy for water pasteurization process and filtration. Thus,filtering water without using any non-renewable source
- The objectives of our project are:
- Removing sediments and particulate matter from water.
- Killing pathogen, viruses and other diseases causing elements from water, thus making it purified.

III DESIGN AND DEVELOPMENT OF SOLAR WATER PURIFIER

The previous chapter gave an introduction and literature review to the project and in this
Chapter we will be discussing the layout and design consideration.

The water purification system comprises of Carbon filter and solar water heater. The experimental layout, components and their functions are explained below.

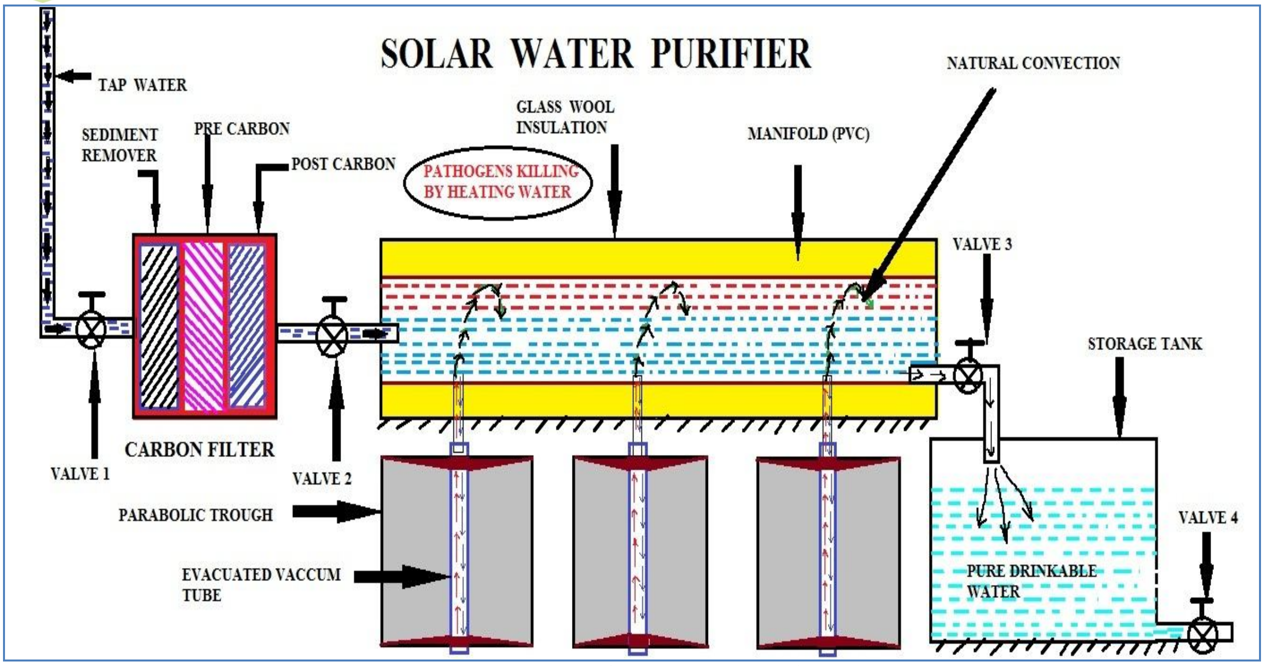

Fig. 1 Layout of solar water purifier

Components of solar water purifier

[1] Parabolic reflector:A parabolic trough is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, lined like a polished metal mirror. The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the lines, where objects are positioned that are intended to be heated. The concentration ratio for parabolic trough ranges from 10 to 80. [5]

[2] Vacuum tube:An evacuated vacuum tube collector consists of two concentric glass tubes with annular space between them being evacuated. The outer surface of inner glass tube is selectively coated. The incoming solar radiation is absorbed on this surface and partly conducted inwards through the tube walls. The inner tube is filled with water and the heat is transferred to the water by thermo syphon circulation. Due to surrounding vacuum the heat loss by convection to surrounding is significantly reduced.

[3] Metal construction:The construction of ribs to hold the SS reflective sheet is made using aluminum and the cutting of ribs is done by laser cutting method. The stand to hold the manifold and tank is constructed of mild steel.

[4] Manifold:Capacity of manifold is 27 liters and is made by PVC. Its outer diameter is 140mm and wall thickness is 3.4mm.The manifold has an outer layer of glass wool in order to prevent heat loss. The thickness of the layer is 30mm.

[5] Carbon Filter: The Carbon filter has 3 parts, which are sediment removal, pre-carbon and post-carbon filter. In first part sediments are removed and then other aesthetics like colour and odour are controlled by pre and post carbon filter. The processing capacity of the filter is 3.7 LPM.The filter can effectively remove sediment particles of size0.5 to 50 micrometers[7].

Design Calculation:

Capacity of Manifold

Taking, capacity of the manifold as 27 litres,

$\therefore Volume_{tank} = \pi/4 \times D_{tank}^2 \times L_{tank} = 27 \times 10^{(-3)}\ m^3$

$\therefore D_{tank}^2 \times L_{tank} = 0.03437 m^3$

Calculation of Incident Radiation

For the Month of January

Solar Insolation= 4.74 Kwh/m^2/day[9]

$\therefore Q_{incident} = 4.74 \times 1000 \times 3600\ Joules/m^2/day$

$\therefore Q_{incident} = 17.064 \times 10^6\ Joules/m^2/day$

$\therefore Q_{incident} = 197.5\ Watt/m^2$

Area of aperture of parabolic trough

Let the length of the trough = L_T

Let the width of the trough = W_T

∴ Area of one trough= $L_T \times W_T$

Let us consider that we are using “n” no. of troughs.

∴Total aperture area=Aperture area of one trough × n

∴$A_{total}=L_T \times W_T \times n$

∴Length of Vaccum Tube=1.5m

d_{in}=37mm

d_o=47mm

L_T=1.3m(subtracting 10cm from both sides of the tube for mounting purpose)

Taking width, W_T=0.7m

On the basis of that,

Concentration ratio,(C.R)

C.R=(Aperture area of trough)/(Surface area of Vacuum tube)

∴$C.R=(W_T \times L_T)/(\pi \times L_T \times d_o)$

∴$C.R=(0.7 \times 1.3)/(1.3 \times 47 \times 10^{-3})$

∴C.R=4.74

Net heat required to boil water (without considering losses)

Total heat required = $Q_{required}=Q_{tank}+Q_{(vacuum\ tubes)}$

∴$Q_{required}=(mC_p \Delta T)_{tank}+(mC_p \Delta T)_{tube}$

∴ $Q_{required}=27 \times 4.18 \times (100-25)+n \times 1.62 \times 4.18 \times (100-25)$

∴$Q_{required}=(8464.5+n \times 507.87)$ KJ

Total heat available from the sun:

[2]$Q_{available}=Q_{incident} \times$ Reflectivity of sheet $\times A_{Total} \times \eta_{tube} \times C.R$

∴$Q_{available}=197.5/10^3 \times 0.55 \times (0.7 \times 1.3 \times n) \times 0.6 \times 4.74$

∴ $Q_{available}$=0.2811n KJ/sec

So, in 1 second heat available=0.2811n KJ.

Therefore, in 4 hours, heat available=0.6489n×4×3600

∴$Q_{availble}$=4048.21n KJ

Manifold Design:

Selecting manifold material as PVC, due to its low thermal conductivity, low cost, high flash point and it is easily available.

Taking, standard pipe [11] of 140mm outer diameter and 3.4mm thickness

Outer Diameter (O.D) = 140mm

Inner Diameter (I.D) = O.D-2×thickness of wal =140-2×3.4

∴I.D=133.2 mm

i.e.D_{tank}=133.2 mm

Substituting this value in equation (1), we get

$(133.2 \times 10^{-3})^2 \times L_{tank}=0.03437$

∴L_{tank}=1.93

Thermal aspects of manifold[12]

Material= PVC

Thermal conductivity= k_{pvc}=0.19 W/mK[13]

Emissivity(e)=0.91[13] Let the inside temperature of the manifold be T_1, outside temperature be T_2 and the temperature of the ambient air beT_a.

The manifold holds water from25°C to 100°C, so considering the mean temperature.

∴$T_1=(25+100)/2$

∴T_1=62.5°C

Let, the convective heat transfer coefficient of the outside air be h_a.
It is given by the following relation,

$h_a=10.45-v+10\sqrt{v}$[14]
Where, v= velocity of air (m/s)
Valid for velocities between 3 to 20 m/s

Now, wind velocity in Vashi in the month of January is 3.02 m/s.[15]

$\therefore v=3.02$ m/s

So,$h_a=10.45-3.02+10\sqrt{3.02}$

$\therefore$ $h_a=24.808$ W/m^2 K Let, R_1 be the conductive resistance of the PVC pipe and R_2 be the convective resistance of the outside air.

Now the next step is,

$R_1=(\ln(r_o/r_i))/(2\pi k_{pvc}\times L_{tank})$

$\therefore R_1=(\ln(70/66.66))/(2\pi\times0.19\times1.93)$

$\therefore R_1=0.0216°C/W$

Also,

$R_2=1/(h_a\times\pi\times D_o\times L_{tank})$

$\therefore R_2=1/(24.808\times\pi\times(140\times10^{-3})\times1.93)$

$\therefore R_2=0.04748°C/W$

Therefore, $R_{total}=R_1+R_2$

$\therefore R_{total}=O.06908°C/W$

Now, loss due to conduction and convection is given by,
$Q_{loss1}=\Delta T/R_{total}$
$\therefore Q_{loss1}=(T_1-T_a)/R_{total}$
Taking atmospheric temperature, $T_a=25°C$
$\therefore Q_{loss1}=(62.5-25)/0.06908$

$\therefore Q_{loss1}=542.84$ watts

In one second the Heat loss is542.84×10^{-3} KJ, so the heat lost in 4 hours is given as,
$Q_{loss1}=(4\times3600\times542.84)/10^3$

$\therefore Q_{loss1}=7816.89$ KJ

Since the Heat lost is high, we are introducing glass wool (insulator $k_{wool}=0.032$W/mK[16]) of thickness 30mm as per standard size available in market.

Resistance to heat flow offered by glass wool
$R_3=\ln(r_g/r_o)/(2\pi\times k_{wool}\times L_{tank})$
$\therefore R_3=\ln(100/70)/(2\pi\times0.032\times1.93)$

$\therefore R_3=0.9191$ °C/W

So the convective resistance R_2 changes to,
$R_2=1/(h_a\times\pi\times(D_0+2\times30)\times L_{tank})$
$\therefore R_2=1/(24.808\times\pi\times(200\times10^{-3})\times1.93)$

s$\therefore R_2=0.033°C/W$

So the total resistance becomes,

$R=R_1+R_2+R_3$

$\therefore R=0.9737$℃/W
Now the next step is,
$Q_{loss1}=(62.5-25)/0.9737$

$\therefore Q_{loss1}=38.51$ watt

In one second the Heat loss is38.51×10^{-3} KJ, so the heat lost in 4 hours is given as,
$Q_{loss1}=(4\times3600\times38.51)/10^3$

$\therefore Q_{loss1}=544.58$ kJ

Now finding the surface temperature 〖 T〗 _3,

∴38.51=(T_3-62.5)/(0.0216+0.9191)
∴T_3=26.27℃
Now finding radiation losses,
The emissivity of glass wool is 0.02[17]. So radiation loss is,
Q_radiation=σAϵ(T_3^4-T_a^4)[18]

∴Q_radiation=5.67 × 〖10〗 ^(-8)× π ×200 × 〖10〗 ^(-3) × 1.93 × (〖299.27〗 ^4- 〖298〗 ^4)
∴Q_radiation=9.30 watt

In one second the Heat loss is9.30 × 〖10〗 ^(-3) KJ, so the heat lost in 4 hours is given as,
Q_radiation=(4 × 3600 × 9.30)/ 〖10〗 ^3
∴Q_radiation=133.95 kJ
So, the total heat required is,
Q_required=8464.5+507.87n+544.58+133.95
Equating to Q_available we get,
n=2.58≈3
By considering all the heat losses from the calculation we found that numbers of trough required are three.
Summarizing design dimensions of all components,

[6] Table 2.2 Summary of design calculations

Components	Dimensions(m)	Quantity
Manifold	L=1.93,I.D=0.1332,O.D=0.140	1
Parabolic trough	L=1.3,W=0.7	3
Vacuum tubes	L=1.5,I.D=0.037,O.D=0.047	3

III. CONCLUSIONS

The design is meant to provide 25 liters of water per day and will be best usable during the summer seasons in india. The estimated cost of our project is around Rs15850/-. All the components required for fabrication are available in the market.

REFERENCES

[1] Matthias Günther, Michael Joemann, and Simon Csambor, 2011, Advanced CSP Teaching Materials, “Parabolic Trough Technology”. http://www.energyscience.org/bibliotheque/cours/1361468741Chapter%2005%20parabolic%20trough.pdf
[2] Donald Jeremy Gaitan Cal Poly, San Luis Obispo, CA Fall Quarter 2012, “Design, Construction, and Test of a Miniature Parabolic Trough Solar Concentrator”. http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1034&context=bmedsp
[3] Risch Tratschin, Sustainable Sanitization and Water Management (SSWM), “Solar Pasteurization”. http://www.sswm.info/category/implementation-tools/water-purification/hardware/point-use-water-treatment/solar-pasteurisation
[4] Roxanne Johnson and Tom Scherer, North Dakota State University (NDSU), “Filtration: Sediment, Activated Carbon, Mixed Media”, NDSU publications WQ-1029(Revised). www.ag.ndsu.edu/pubs/watsys.html
[5] S P Sukhatme, J K Nayak, “Principles of Thermal Collection and Storage”, Solar Energy, Third Edition, Tata MacGraw Hills publications, pp. 203.
[6] Backcountry Drinking Water, [On-Line Article], [June 05, 2011] http://backcountrywater.com/water-treatment-methods/heat-treatment-boiling/heat-treatment-boiling/