Solar Water Purification using Carbon Filter and Evacuated Tube

Sharayu Wasu[1], V.G. Gore[2],D.V. Bhile[3]
Department of Mechanical Engineering
[1,3] P .R .Pote College of Engineering Amravati, India
[2] Professor, P .R .Pote College of Engineering Amravati, India

Abstract- *Carbon filters are very effective at removing chlorine, benzene, radon, solvents 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 odour from the water. By 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 conduction heat loss, therefore achieving greater efficiency than flat-plate collectors.*

Keywords- Solar, Water Purifier, Thermal distillation, carbon filter, sediment filter, parabolic collector

I. INTRODUCTION

Energy is essential for the economic growth and social development of any country. The quality of life is closely related to energy consumption, which has continuously increased over the last few decades in developing countries. Water is essential for human it comprises around 60% of the weight of human.Safe drinking water is the basic need of human beings.Butmicrobial contamination of drinking water is a major health hazard. The universal problem still needs more collaboration in order to minimize the number of people in need for drinkable water. The system designed will mainly target the transformation of impure water into drinkable water using carbon filter and PTC (parabolic trough collector) with evacuated tube technology. This technology works by passing water through carbon filter and then concentrating the sunlight into the pipes i.e. evacuated tube through parabolic trough type collector. A solar water purifier is long term investments that will save money spend on water purification after the system has paid for itself. In addition to the reduced electricity energy and cost saving from water purification, there are several other benefits derived. The use of a solar water purification system improves environmental impact and reduces greenhouse gas emission through less or zero use of fossil fuelsActivated carbon is commonly used for removing organic constituent and residual disinfectant in water supplies. It improves taste and minimizes health hazards. Activated carbon is commonly used in water treatment to remove water contaminants from tap water and well water. Activated carbon is used in home water filtering system due to its excellent adsorption capacity.

The evacuated tube is the central components of the heating as well as purification systems and the tube is made up of two concentric borosilicate glass tubes. The sun light is incident on the evacuated tube. It passes through the outer glazing and reaches the inner glazing. The reflectors below the evacuated tubes reflect the solar radiation and so the incident energy on the evacuated tubes is augmented. As the inner glazing's are black coated, they absorb the incident energy and get heated up. The generated heat is transferred to liquid passing through the glasses. The hot water goes to the storage tank due to the differences in density and it is stored in the storage tank. The whole process is continued during the sunshine hours.

II. REVIEW OF LITERATURE

The literature review was mainly carried out to know various developments related to solar water purifiers from last decades. This gives better understanding regarding the concept of solar water purification analysis and experimental investigation related to solar technology. Article from journal and conference where studied which included latest analysis and experimental investigation related to solar water purification process. The numbers of researches were presented by the different researcher for analysis of solar water purification process.

Apricus Australia [1];Evacuated tubes work in all seasons and are more efficient at higher temperature differentials, such as during colder weather or when trying to achieve high target temperatures. Evacuated tubes can be positioned more favorably towards the sun than flat plate. Can be up to 45o either side of north pointing and still achieve

good solar collection. At temperatures of around 100oC the efficiency of a flat plate is virtually negligible while an evacuated tube collector can still be converting 50+% of available sunlight into heat energy (based on absorber area). For this reason evacuated tube collectors are required for any applications requiring higher temperatures. Flat plate collectors have their place in the market, but when you want higher temperatures or performance in cooler weather, evacuated tubes have a huge advantage over flat plate collectors.

Shwetharani.R.[2];The availability of decontaminated water is a serious environmental problem in both developed and underdeveloped countries in the 21st century. Access to fresh water will become even more important in the near future, as the world's population rises from 7 billion today to 9 billion by 2050. The World Health Organization (WHO) has estimated that 80 percent of illnesses in the developing world are water related, resulting from poor water quality and lack of sanitation. 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhea and 73 million working days are lost due to waterborne disease each year [6] caused by bacteria such as Escherichia coli, Salmonellasp. and Cholerasp., parasites and viral pathogens. Many infectious diseases are transmitted through the faecal oral route and in countries where sanitation practices are less than adequate, faecal contamination of water supplies is a common occurrence. Activated carbon is commonly used for removing organic constituents and residual disinfectant in water supplies. This not only improves taste but also minimize health hazards. Activated carbon is used in home water filtering system due to its excellent adsorption capacity. A sediment and carbon filtration process can purify water so that it can be drinkable. This is the reason for the use of activated carbon as major filter medium in most of the water filtration system.

ShoufengQiu,MatthiasRuth,SanchariGhosh[3];Alt hough Evacuated Tube Collector And Flat Plate Collector have their own technological advantages and disadvantages and also economic advantages that evacuated tube Solar Water Heater and Purifier have over flat plate Solar Water Heater and Purifier. The low initial cost and the short payback period have in Evacuated Tube Solar Water Heater and Purifier's installation have been found to be the main factors behind the popularization of Solar Water Heater as shown in many studies. Initial cost of evacuated tube Solar Water Heater and Purifier has been lower than that of flat plate Solar Water Heater and Purifier.Not only the efficiency of Evacuated Tube is more but also according to economical point of view it is affordable.

III. SOURCES OF WATER

Groundwater: The water emerging from deep ground water may have fallen as rain many teens, hundreds, and thousands or in some cases millions of years ago. Soil and rock layers naturally filter the ground water to a high degree of clarity before it is pumped to the treatment plant. Such water may emerge as springs, artesian springs, or may be extracted from bore holes or wells. Deep ground water is generally of very high bacteriological quality (i.e., pathogenic bacteria or the pathogenic protozoa are typically absent), but the water typically is rich in dissolved solids (TDS).

Upland lakes and reservoirs: Typically located in the headwaters of river systems, upland reservoirs are usually sited above any human habitation and may be surrounded by a protective zone to restrict the opportunities for contamination. Bacteria and pathogen levels are usually low, but some bacteria, algae and protozoa might be present.

Rivers, canals and low-land reservoirs: Low-land surface waters have a significant bacterial load and may also contain algae, suspended solids and a variety of dissolved constituents.

Atmospheric water generation: it is a new technology that can provide high quality drinking water by extracting water from the air by cooling the air and thus condensing water vapor.
Rainwater harvesting or fog: collection which collects water from the atmosphere can be used especially in areas with significant dry seasons and in areas which experience fog even when there is little rain.

IV. OVERVIEW OF WATER PURIFICATION PROCESS

Clean and safe water is vital for everyday life. Water is essential for health, hygiene and the productivity of our community. The water treatment and purification process may vary slightly at different locations, depending on the technology of the plant and the water it needs to process, but the basic principles are largely the same. This section describes standard water treatment and purification processes.

ACTIVATED CARBON: Carbon filters are very effective at removing chlorine, benzene, radon, solvents 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 odour from the water

SEDIMENTATION: Sedimentation, or clarification, is the processes of letting suspended material settle by gravity. Suspended material may be particles, such as clay or silts, originally present in the source water. Suspended material or floc is typically created from materials in the water and chemicals used in coagulation or in other treatment processes. Sedimentation is accomplished by decreasing the velocity of the water to a point which the particles will no longer remain in suspension. When the velocity no longer supports the particles, gravity will remove them from the water flow. Sand or silt can be removed very easily because of their density .The size and type of particles to be removed has a significant effect on the operation of the sedimentation tank.

EVACUATED TUBE COLLECTOR: The Evacuated tube collector consists of a number of rows of parallel transparent glass tubes connected to a header pipe and which are used in place of the blackened heat absorbing plate called flat plate collector. These glass tubes are cylindrical in shape. Therefore, the angle of the sunlight is always perpendicular to the heat absorbing tubes which enables these collectors to perform well even when sunlight is low such as when it is early in the morning or late in the afternoon, or when shaded by clouds. Evacuated tube collectors are particularly useful in areas with cold, cloudy wintry weathers.Evacuated tube collectors are made up of a single or multiple rows of parallel, transparent glass tubes supported on a frame. Each individual tube varies in diameter from between 1" (25mm) to 3" (75mm) and between 5′ (1500mm) to 8′ (2400mm) in length depending upon the manufacturer. Each tube consists of a thick glass outer tube and a thinner glass inner tube, (called a “twin-glass tube”) or a “thermos-flask tube” which is covered with a special coating that absorbs solar energy but inhibits heat loss. The tubes are made of borosilicate or soda lime glass, which is strong, resistant to high temperatures and has a high transmittance for solar irradiation.

V. FACTORS AFFECTING SOLAR WATER HEATING AND PURIFICATION PROCESS:

The performance a solar water heating depending on the following factor

1) Ambient condition
2) Collector orientation and tilt.
3) Collector array arrangement
4) Collector and storage tank
5) The transport fluid flow rate

VI. EXPERIMENTAL SETUP:

From the reservoir, water comes to sediment filter at first which is primary filtration method in which water getsediment and rust flakes from the water pipes, sand grains, small pieces of organic matter, clay particles, or any other small particles in the water supply get removed. Then the water enters to the carbon filter which is secondary filtration process, rust flakes from the water pipes, sand grains, and small pieces of organic matter, clay particles, or any other small particles in the water supply. Water get half filtered through this process but bacteria and viruses are still be there in water and then water get stored into manifold through a valve. Manifold is a steel tank insulated with wood wool and MDF sheet box. The manifold has four openings for inlet of water, delivery of water, an air vent and an opening for evacuated tube. Water coming through the valve is of having ambient temperature which is then enters into the evacuated tube. The water in the evacuated tube get heated and hot water goes upward and cold water goes downward in the tube through thermosyphon effect. The density of hot water is less and the density of cold water is more hence ultimately hot water goes upward on the tank. The water in the tube is heated upto 100°c therefore all bacteria and viruses get eliminated through the process and water get fully purified. As the manifold filled up close the first valve and drain out the water through the delivery valve and stored it.

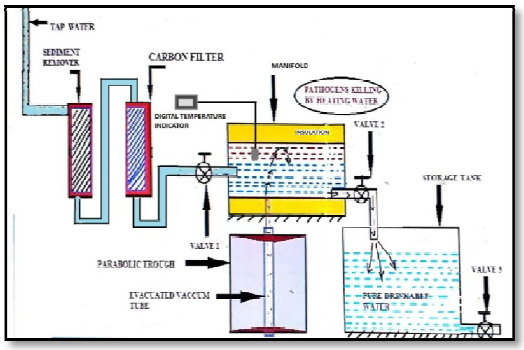

Fig 1: solar water purifier with evacuated tube and carbon filter

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.

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.

Metal construction:

The construction of ribs to hold the reflective sheet is made using aluminum. The stand to hold the manifold and tank is constructed of cast iron.

Manifold:

Capacity of manifold is 10 liters and is made by steel. 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.

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.

Sediment filter:

The filter can effectively remove sediment particles of size0.5 to 50 micrometers

Safety:

There are certain precautions to be taken

- Firstly avoid direct exposure of any body part to the focal line as it might burn the contact area.
- The vacuum tube is very fragile and should be handled carefully
- Make sure there is water at all times in the vacuum tube to avoid heat accumulation.
- When not in use the reflective sheets should be covered so that there is no heat generated.

Cleaning:

All the parts such as the vacuum tube, steel vessels, etc have to be cleaned with water once a month so that there is no accumulation of untreated water. The reflective mirror has to be cleaned regularly so that it doesn't lose its reflectivity. Covering the setup with a cloth would be advisable when not in use to protect it.

VII. CALCULATION

1) Capacity of Manifold

Taking, capacity of the manifold as 10 liters,
$\therefore$Volume of tank = $(\pi/4) \times D^2 \times L$
$10 = (\pi/4) \times D^2 \times L$
$\therefore (D^2 \times L) = 0.01273 m^3$
Where
D is diameter of manifold.
L is length of manifold.

2) Calculation of Incident Radiation

For the Month of May
Solar Irradiation= 4.74 Kwh/m²/day [6]
$\therefore$(Q)incident=4.74×1000×3600Joules/m²/day
$\therefore$(Q) incident= 17.064 $\times(10)^6$ Joules/m²/day
$\therefore$ (Q) incident= 197.5 Watt/m²

3) Area of aperture of parabolic trough

Let the length of the trough = L
Let the width of the trough = W
$\therefore$ Area of one trough = (L×W)
Let us consider that,
We are using "n" no. of troughs.
$\therefore$Total aperture area=
(Aperture area of one trough × n)
$\therefore$Total aperture area = (L ×W × n)
$\therefore$Length of Vacuum Tube=1.8m=0.0018m
Inner diameter of vacuum tube=48mm
Outer diameter of vacuum tube = 58mm
Length of vacuum tube=1.8m
Length of vacuum tube for calculation=1.6m
(Subtracting 10cm from both sides of the tube for mounting purpose)
Taking width (trough), W=0.8m

4) Concentration ratio, (C.R)

On the basis of above data.

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

∴C.R=(W×L)trough/(π×L×outerdiameter)tube

∴C.R= (0.8×1.6 /(π× 1.6 × 0.058)

∴C.R= (1.28) / (0.2915)

∴C.R= 4.39

5) Net heat required to boil water (without considering losses)

Total heat required i.e. (Q) required=

(Q) manifold + (Q) vacuum tubes

∴Q required=

(m Cp ΔT) manifold + (m Cp ΔT) tube

∴Qrequired=[(10×4.18×(100-25)]+[0.54×4.18× (100-25)] n

Where

Ambient temp of water=25°C

Boiling temp of water= 100°C

∴Q required= (3135 + n×169.29) KJ

6) Total heat available from the sun

(Q) Available = (Q)incident × (Reflectivity of sheet) × (A)trough × (n)no. of tube × (C.R)

∴ (Q) available=(197.5×10^{-6})×(0.55)× (0.8×1.6)× (n) ×0.6×(4.39)

Where,

Efficiency of tube=o.6

∴ (Q) available= 0.3662n KJ/sec

Let,

7) Now, loss due to conduction and convection is given by,

Q_loss1=(ΔT/R_total)

∴Q_loss1=(T1-Ta)/R_total

Taking atmospheric temperature, Ta=25℃

∴Q_loss1=(62.5-25)/ 0.1337

∴Q_loss1=281.95 watts

In one second the Heat loss is0.281.95KJ

Since the Heat lost is high,

we are introducing wood wool (insulator k_wool=0.032W/mK) of thickness 30mm as per standard size available in market.

Resistance to heat flow offered by glass wool

R3= [ln(r_g/r_o)/ (2π×k_wool×L_tank)]

∴R3=ln [(100/70)/(2π×0.032×0.64)]

∴R3=2.771 ℃/W

So the convective resistance R2 changes to,

R2= 1/(h_a×π×(D_0+2×30)×L_tank)

∴R_2= 1/(24.808×π×0.2×0.64)

∴R2=0.1002℃/W

So the total resistance becomes,

R=R1+R2+R3

∴R=(0.1337)+(2.771)=2.904□/W

Now the next step is,

Q_loss1= (ΔT/ R)

Q_loss1=(62.5-25)/2.904

∴Q_loss1=12.91 watt

Now finding the surface temperatureT3,

(Q)loss=(T3-62.5) /(R1+R3)

∴12.91 =(T3-62.5)/(0.06398+2.904)

∴T3=27.81℃

8) Now finding radiation losses,

The emissivity of glass wool is 0.02.

So radiation loss is,

(Q) radiation= σAϵ(T^4-Ta^4)

∴(Q)radiation=[5.67×10^(8)]×[π×200×10^3]× [0.64]×[300.1^4-298^4]

∴(Q)radiation= 9.30 watt

So, the total heat required is,

(Q) required=8464.5+507.87n+544.58+133.95

Equating to (Q) available we get,

n=0.866≈1

By considering all the heat losses from the calculation we found that numbers of trough required is one.

Summarizing design dimensions of all components,

VIII. CONCLUSION

This study presented is a comparative analysis on the feasibility of water purifying method.As solar energy is being used for the purification of water, which is cheap and abundant, it can be used everywhere where electricity is not available.Complete and satisfactory working was achieved using the carbon filter and evacuated tube with parabolic trough collector under conditions of sunlight or for intermittently sunny or cloudy conditions.Filter as well as disinfector, pre-filter i.e. sediment filters completely purify the water and make it drinkable.This project is used to purify water from stream, pond water, lake or any fresh water source.The design is meant to provide 10 liters of water per day and will be best usable during the year around in India.This project has only capital cost and almost no running cost. The estimated cost of our project is around Rs11850/-. All the components required for fabrication are available in the marketHence, it will prove to be useful in the near future.

IX. FUTURE SCOPE

Water purification is one of the most rapidly developing fields in the world.As the consumption of clean water increase which is obtain without using electricity, solar water purifier with evacuated tube and carbon filter will play a major role in this field.Solar water purifier is utilizing for several application.Installing a solar water purification system for your home or any other place can reduce your electrical energy consumption because it works without electricity. It takes 1 evacuated tube to heat over 10 liter of water to purify. Because single tube is enough to raise the temperature of 10 liter water to 100°C in a short time which makes the water completely safe for drinking purpose.In this kind of purifier very high temperature i.e. greater than 100°C can be achieved at peak hours of the day, which can be utilized for other useful purpose by attaching a suitable size of heat exchanger.

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