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Research Article

The experimental analysis applied to an evacuated tube solar collector equipped with solar parabolic trough and carbon filter for purification of water

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Abstract: Carbon filters are vital at eliminating elements such as chlorine, radon, benzene, solvent, compounds, volatile organic chemicals, pesticides, herbicides, lots of man-made chemicals and a particle are contact with tap water and removes the bad tastes and odor of the water. Initially by carbon filter water is purified then passed to evacuated vacuum tubes for further purification. A solar thermal collector is parabolic trough with a polished mirror-like finish metal straight in one dimension and curved as a parabola in the other two dimensions. The energy of sunlight reflects and focused along the focal line on vacuum tube

Keywords: Water Purifier, carbon filter, parabolic collector, evacuated tube

1. Introduction

Energy is a must for the economic increase and public advancement of any nation. The worth of living is strongly related to power expenditure, which has incessantly amplified over the previous few decades in developing nations. Water is vital for individual beings, and it consists of more than 60% of the mass of a human. Secured drinking water is the fundamental call for of individual beings. But microbial stain of drinking water is a key health danger. The general difficulty still wants more alliance to reduce the quantity of people in require of drinkable water. The system designed will target the impure water into drinkable water using a carbon filter and parabolic trough collector with evacuated tube technology. This technology works by passing water through a carbon filter and concentrating the sunlight into the pipes, i.e., an evacuated tube through a parabolic trough type collector. A solar water purifier is a continuing deal that will keep capital used up on water purification following the system has compensated for itself. Also, along with the reduced electricity power and money-saving from the water purification, there are numerous other profits extracted. The use of a solar water purification system improves environmental impact and reduces greenhouse gas emission through less or zero use of fossil fuels. Charged carbon is normally used for eliminating organic components and remaining disinfectants in water supplies and water purification to eliminate water contaminants from tap water and well water; it improves taste and reduce health hazards. Activated carbon is use in home water purification systems due to its excellent adsorption capacity.

The evacuated tube is the central component of the heating as well as purification systems, and the tube is prepared with two concentric borosilicate glass tubes. The radiation from the sun is focused on the evacuated tube through trough; it passes through the outer covering of tube and reach to the surface coating of The reflectors underneath the evacuated tubes reflect the radiation, so the incident energy on the evacuated tubes is concentrated inner tube . As the internal glazing is black covered with a selective coating, they absorb the incident energy and get worm up. The obtained heat is transferred to working fluids passing through the glass tube. The heated water goes to the tank due to density differences by Thermosyphon effect. The complete method is runs for the period of sunshine hours.

2. Review of Literature

The literature review was mainly carried out to know various developments related to solar water purifiers from the last decades. This gives a better understanding of the concept of solar water purification analysis and experimental investigation related to solar technology. Articles from journals and conferences were studied, including the latest analysis and experimental investigation associated with the solar water purification process. The numbers of researches were presented by the different researchers for analysis of the solar water purification process.

Papadimitratos A, Sobhansarbandi S, Pozdin V, Zakhidov A, Hassanipour F [1] In all season evacuated tubes works but at higher temperature it gives more profitable results. Glass tubes can be located more focused in the direction of sun than a flat plate. Almost 45^{o} both side of north face attain superior solar collection. At

temperatures of approximately 100°C, flat plate collector is not that much efficient than evacuated tube collector because evacuated tube collector converts 50+ % of incident solar radiation into heat energy. This means, for higher temperature application evacuated tube collectors are preferred. By comparing the flat plate collectors the evacuated tubes gives better performance in cooler weather, evacuated tubes have huge benefits over flat plate collectors.

Shwetharani R. [2] The accessibility of fresh clean drinkable water is a severe environmental problem in all over the countries in the world at 21st century. The world's population rises up to 9 billion by 2050, right to use of fresh clean water will become even more important in the future. The 80 percent of illnesses in the developing world are water-related from poor water quality and lack of sanitation is calculated by World Health Organization. Millions of people in India are infected by water-borne diseases yearly, due to diarrhea nearly 2 million of children are estimated to die, and due to water-borne disease 70 million working days are lost each year caused by bacteria Escherichia coli, Salmonellasp, Cholerasp, parasites and pathogens. Several infectious diseases are transmitted throughout the faecaloral way, and in world where sanitation practices are fewer than sufficient, faecal contamination of water supplies is a commonly happening. Activated carbon is frequent used for eliminating organic partials and left over disinfectants in water supply. It improves the taste and reduces health hazards. Activated carbon has excellent adsorption capacity hence commonly used in home water filter. The water purified by sedimentation and carbon filtration process becomes drinkable water. Hence, most of the filtration system Activated Carbon commonly use.

Shoufeng Qiu, Matthias Ruth, Sanchari Ghosh [3] Although Evacuated glass Tube Collector And Flat Plate Collector have scientific and economic advantages and disadvantages, 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 has been found to be the main factors behind the popularization of Solar Water Heater as shown in many studies. The 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 the economic point of view it is affordable.

Ashish Khelkar, Biplab Kumar Debnath, Kishore Debnath [4] In this paper, the main aim is to prepare a sinusoidal profile inside of an receiver tube, study with various fluids for its feasible purpose in a parabolic trough solar collector. The thermo-hydraulic performances of the receiver tube with the sinusoidal profile are identified for 4000 Reynolds number, based upon above *Re* the velocity of the fluids are calculated, The receiver tube has a length of 2m, with inner and outer diameters of 19mm and 25mm. The heat flux of 818.5 W/m^2 is provided at the lower face, which is focused towards the reflector of the PTC. The thermo-hydraulic performances of the receiver tube with sinusoidal profile are reported to improved performance to that of the other type of receiver tube.

3. Sources of water

Groundwater: Millions of years back fallen rain is now deep ground water, this water rising now days. Ground water is naturally filtered with the help of soil, rock layers to a high level of clearness before it is pumped to the filtration plant. Ground water stores in spring, and extracted from boreholes or wells. The groundwater contains several bacteriological qualities such as pathogenic bacteria and pathogenic protozoa and the water also rich in Total dissolved solids (TDS).

Lakes and upland reservoirs: The lakes and reservoirs nearly situated to river, upland reservoirs are generally located near human territory bounded by a defensive area to restrict the contamination of Bacteria, pathogen so reservoir have little quantity of damaging pathogens and bacteria, a few bacteria, algae, and protozoa may be there.

Rivers, canals, and low-land reservoirs: Low-land reservoir has a major bacterial contamination such as algae, suspended solids, and various dissolved constituents in comparison to upland reservoir.

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

4. Overview of Water Purification Process

Clean and safe water is very important for everyday life. Water is essential for the health, hygiene, and productivity of our centre of population. The water management and cleansing process vary slightly at different location, depending on the machinery of the plant and the water it needs to process. Still, the basic principles are fundamentally the same. This section describe standard water treatment and decontamination processes.

Activated Carbon: Carbon filter removes chlorine, solvents compounds, benzene, radon, volatile organic chemicals, pesticides and herbicides, lots of artificial chemicals contacted with tap water also remove bad tastes and odour.

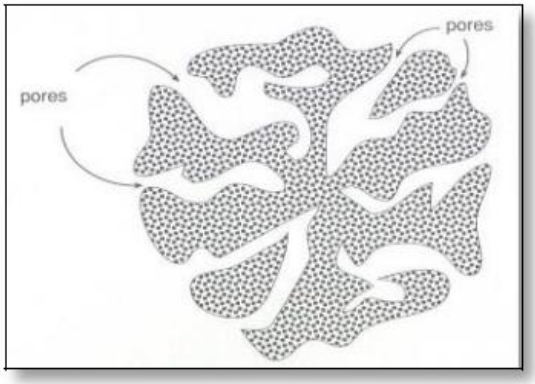

Fig 1 (a): Microscopic view of Activated Carbon

Fig 1 (b): Insider view off carbon filter

Sedimentation: Sedimentation is the process of allow suspended particle settle by gravity. Suspended particle such as clay or silts or floc is typically created from materials in the water and chemicals used in coagulation or other treatment processes. Sedimentation is accomplished by minimising the water velocity, the particles will settle. The velocity no longer ropes the particles, gravity eliminate from the water flow. Sand or silt has low density so that it removes quickly. The types, size of particles to be eliminated have an important result on the process of the sedimentation tank.

Evacuated Tube Collector: The Evacuated tube collector consists of many rows of parallel transparent glass tubes supported on a frame. These glass tubes are cylindrical in shape. The angle of the sunlight is perpendicular to evacuated tubes, allows collectors to perform efficient roles even when sunlight is low in the morning, afternoon, shaded by clouds. In cold, hazy, winter weather evacuated tube collectors are mainly preferred. Tube varies in diameter range of 25 mm to 375 mm, 1500 mm to 2400

mm in length, depending upon the manufacturer. Each tube consists of outer thick glass tube and a thin internal glass tube called a twin-glass tube or a thermos-flask tube covered with a special coating absorbs solar energy but inhibit heat loss. The tubes are made up of borosilicate or soda-lime glass peruse the properties like strong, resistant to high temperatures, and has a high transmittance for solar irradiation.

Factors Affecting Solar Water Heating and Purification Process

The performance of 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

5. Experimental Setup

From the reservoir, water comes to sediment filter at first which is the primary filtration method in which water gets sediment and 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 get removed. Then the water enters the carbon filter, which is a 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 gets half filtered through this process, but bacteria and viruses are still there in the water, and then water gets stored into the manifold through a valve.

Manifold is a steel tank insulated with wood wool and an MDF sheet box. The manifold has four openings for an inlet of water, delivery of water, an air vent, and an opening for an evacuated tube. Water coming through the valve is of having an ambient temperature which is then entered into the evacuated tube. The water in the evacuated tube gets heated, hot water goes upward, and cold water goes downward in the tube through the 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 up to 90°c; therefore, all bacteria and viruses get eliminated through the process, and water gets fully purified as the manifold is filled up close to the first valve and drain out through the delivery valve and stored.

Fig 2: solar water purifier with evacuated tube and carbon filter

Parabolic reflector- A parabolic trough is solar thermal collector straight in one dimension and curved as a parabola in the other two, lined like a polished metal mirror. The energy of sunlight that enters the mirror parallel to its plane of symmetry is focused along the lines, where objects are sited that are proposed to be heated.

Vacuum tube- An evacuated vacuum tube having two concentric glass tubes, vacuumed within them. The outer face of the inner glass tube is selectively coated. The length of tube is 1.8m long. The 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 thermosyphon process. Due to the vacuum between tubes, the short wave radiation trap within the vacuumed, heat loss by convection to the surrounding reduces.

Metal construction:

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

Fig 3: Metal Construction

Manifold

The manifold store 10 liters of working fluids and is made of steel. Its external diameter is 140mm, and wall thickness is 3.4mm. The manifold has an external coating of glass wool in order to avoid heat loss. The thickness of the layer is 30mm.

Carbon Filter:

The carbon filter divided into three parts, such as sediment removal, pre-carbon, and post-carbon filter. In the first part, sediments are eliminating, and then other aesthetics like color and odor are reduces by pre and post-carbon filters. The filtering power of the filter is 3.7 LPM

Fig 4: Carbon Filter

Sediment filter:

The filter can effectively remove sediment particles of size 0.5 to 50 micrometers.

Safety Precautions:

There are certain precautions to be taken

1. Firstly, avoid direct exposure of any body part to the focal line as it might burn the contact area.
2. The vacuum tube is very fragile and should be handled carefully
3. Make sure there is water at all times in the vacuum tube to avoid heat accumulation.
4. 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.

6. Calculation

1. Capacity of Manifold

Taking, capacity of the manifold as 10 liters, ∴Volume of tank = $(\pi/4) \times D^2 \times L$ $10 = (\pi/4) \times D^2 \times L$

∴ $(D^2 \times L) = 0.01273 m^3$ 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]

∴(Q)incident=4.74×1000×3600Joules/m²/day ∴(Q) incident= $17.064 \times (10)^6$Joules/m²/day

∴ (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

∴ Area of one trough = (L×W) Let us consider that,

We are using "n" no. of troughs.

∴Total aperture area=

(Aperture area of one trough × n)

∴Total aperture area = (L ×W × n)

∴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=(Aperturereareaoftrough)/(Surfacereareaof Vacuumtube)

∴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= manifold + (Q) vacuumtubes ∴Q required=

(mCp 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

Available=(Q)incident×(Reflectivityofsheet)

× (A)trough × (n)no. of tube × (C.R)

∴ (Q) available=$(197.5\times110^{-6})\times(0.55)\times(0.8\times1.6)\times(n)\times0.6\times(4.39)$

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°C

∴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,

Now finding radiation losses,

The emissivity of glass wool is 0.02. So radiation loss is,

radiation=$\sigma A\epsilon(T^4-Ta^4)$

∴(Q)radiation=[5.67×10^(8)]×[$\pi\times200\times10^3$]×

[0.64]×[300.1^4-298^4]

∴(Q)radiation= 9.30 watt

So,thetotalheatrequiredis,

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

Equating to (Q) available we get, n=0.866≈1

7. Result of Experimental Studies

Table 1: Report of sample before purification

Issued From :- Laxmi industries Ramdara ward No-4, At post Talegaon (SP), Dist- Wardha				Report Date :	18 May 2019
				Lab ID No. :	WT-060419-31
				Report No :	LAL-WT-060419-18
Sr. No.	Test Name	Required Value	Result		Test Method
1	Faecal Streptococci (per 250 ml)	Absent	Present		IS 15186 : 2002

2	Salmonella aurus (per 250 ml)	Absent	Present	IS 15187 : 2016
3	Shigella (per 250 ml)	Absent	Present	IS 5887 (Part-7) : 1999.
4	Zinc (Zn) mgÀl	Max. 5	8	IS 3025 (Part-2) : 2004.
5	Mineral oil	Absent	Absent	IS 3025 (Part-39) : 1991.
6	Antimony (Sb) mg/l	Max. 0.05	0.25	IS 3025 (Part-2) : 2004.
7	Fluoride (F) mg/l	Max. 1	2.06	IS 3025(Part-60) 2008(RA 2013)
8	Sodium (Na) mg/l	Max. 200	368	IS 3025(Part-2) 2004.
9	Bromates (BrO3) mg/l	Max. 0.01	0.018	ISO 15061 : 2001
10	Cyanide (as CN) mg/l	Absent	Absent	IS 3025 (Part-27) : 1986 (RA 2014)
11	Chromium (as CR) mg/l	Max. 0.05	0.1	IS 3025(Part-2) 2004.
12	Arsenic (as As)mg/l	Max. 0.01	Absent	IS 3025(Part-2) 2004.
13	Silver (as Ag) mg/l	Max. 0.01	0.03	IS 3025(Part-2) 2004.
14	Lead	Max. 0.01	0.25	IS 3025(Part-2) 2004.
15	Mercury (as Hg)	Max. 0.001	0.0004	USEPA 200.7 : 1994, Rev 4.4

Table 2: Report of sample after purification

Issued From :- Laxmi industries Ramdara ward No-4, At post Talegaon (SP), Dist- Wardha	Report Date :	20 May 2019
	Lab ID No. :	WT-060419-31
	Report No :	LAL-WT-060419-31

Sr. No.	Test Name	Required Value	Result	Test Method
1	Faecal Streptococci (per 250 ml)	Absent	Absent	IS 15186 : 2002
2	Salmonella aurus (per 250 ml)	Absent	Absent	IS 15187 : 2016
3	Shigella (per 250 ml)	Absent	Absent	IS 5887 (Part-7) : 1999.
4	Zinc (Zn) mgÀl	Max. 5	0.1	IS 3025 (Part-2) : 2004.
5	Mineral oil	Absent	Absent	IS 3025 (Part-39) : 1991.
6	Antimony (Sb) mgÀl	Max. 0.05	0.003	IS 3025 (Part-2) : 2004.
7	Fluoride (F) mgÀl	Max. 1	0.4	IS 3025(Part-60) 2008(RA 2013)
8	Sodium (Na) mgÀl	Max. 200	17.79	IS 3025(Part-2) 2004.
9	Bromates (BrO3) mgÀl	Max. 0.01	0.005	ISO 15061 : 2001
10	Cyanide (as CN) mgÀl	Absent	Absent	IS 3025 (Part-27) : 1986 (RA 2014)
11	Chromium (as CR) mgÀl	Max. 0.05	0.015	IS 3025(Part-2) 2004.

12	Arsenic (as As) mgÀl	Max. 0.01	Absent	IS 3025(Part-2) 2004.
13	Silver (as Ag) mgÀl	Max. 0.01	0.005	IS 3025(Part-2) 2004.
14	Lead	Max. 0.01	0.003	IS 3025(Part-2) 2004.
15	Mercury (as Hg)	Max. 0.001	0.0004	USEPA 200.7 : 1994, Rev 4.4

8. 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 market hence; it will prove to be useful in the near future.

9. 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 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 than100°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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