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Design and Construction of Solar Water Purifier

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Abstract

In Bangladesh, water borne diseases are very common due to scarcity of pure drinking water. 60% of the population has to endure unsafe drinking water. Energy crisis is another important issue. Conventional energy sources are limited and they cause environmental pollution. By using a renewable energy source as solar power to purify water, these problems can be avoided. Solar water purifier is an advancement of current water purification system. Design methodology of the solar water purifier is presented in this paper. Solar water purifier takes solar power as energy source and stores energy in a battery. Main components of solar water purifier are solar panel, battery, heating coil, filtering chalk, double layer condenser and several water vessels. This purifier uses filtering mechanism to remove dirt from water and boiling mechanism to kill organisms. Through this process, pure drinking water is achieved.

Keywords: Solar, Energy, Filtration, Water, Purify.

1. Introduction

Pure drinking water is essential to ensure good health. Contaminated water hampers health by causing several water borne diseases such as Diarrhea, Cholera, Guinea worm disease, Typhoid and Dysentery. In developing countries like Bangladesh, scarcity of pure drinking water is a big issue till now. Diarrheal disease is the country's biggest killer, taking the lives of 62 in 1000 under fives [1]. Besides, dependency on limited energy resources indicate future problem for these countries. During flood and other calamities, intensive public service campaigns alert people to boil their drinking water, but fuel is limited and costly [1]. Leaning towards renewable energy might solve the energy crisis. A water resource should be safe and reliable but also affordable to people. In order to provide a safe and affordable water supply, solar water purifier is a potential solution. Existing water purification systems using solar power are very time consuming and complex in design. Besides, no available solar purifiers are appropriate for personal use and they all are very expensive. So, finding an economic solution which is affordable to people is compulsory. In this paper, economic design and construction of solar water purifier is presented.

2. Functional Decomposition

Functional Decomposition is the process of taking a complex process and breaking it down into its smaller, simpler parts. Black box model reveals conversion of energy, material or signals to achieve a desired outcome [2].

Black box diagram of our Solar Water Purifier is shown in figure 1.

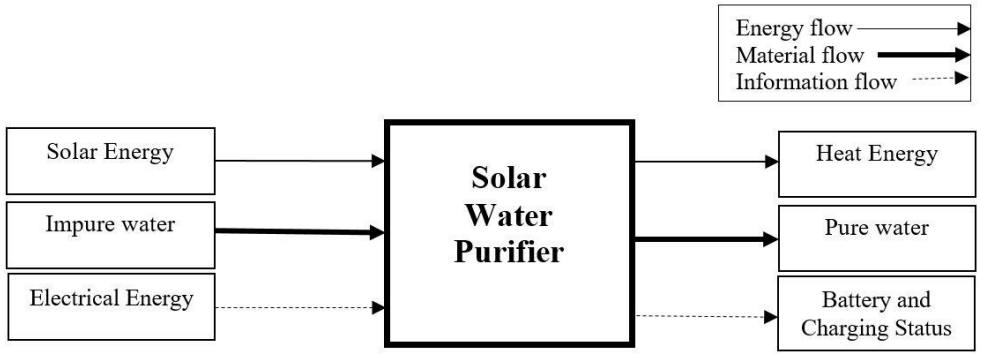


Figure 1. Black box model of the solar water purifier

Energy flow: Solar water purifier will receive and collect solar energy converts this energy into heat.

Material flow: Dirty and impure water is given as input in water purifier and clean drinking water comes out as output.

Information Flow: From electrical energy of solar circuit and battery, controller shows charging status of battery.

3. Components

Main components of solar water purifier are solar panel, battery, heating coil, filtering column, double layer coil condenser and several water vessels. Some auxiliary components are inverter, controller, water tap, wheels for mobility etc.

SolidWorks design of filtering column is showed in figure 2. The first layer consists of gravel to filter out impurities which are visible, the second layer consists of sand which filters out smaller impurities and the third which is the last layer consists of activated charcoal which has a huge internal surface area, packed with nooks and crannies that attract and trap chemical impurities through a process called absorption [3].

Figure 2. Design of filtering column

An AC heating coil is used to increase water temperature.

Solar panel collects energy of sun and converts to electrical energy. Solar battery stores that energy. Inverter is used to convert DC current to AC current. Controller is used to show the charging status of battery and prevent the solar panel to take charge from battery when voltage of battery is higher.

Figure 3 shows a double layer coil condenser. It is more efficient than other existing condensers. It has two layers which enables 2 times cooling than ordinary condenser. Besides, in this condenser, hot water passes through a coil. As a result, the contact period and space between hot and cold water is increased. So, better cooling is obtained.

Figure 3. Double layer coil condenser

4. Mechanism

In this purifier, solar power is used as energy source and energy is stored in a battery. At first, water is filtered by filtering chalk to remove dirt and impurities. Then using stored energy, it boils water by using a heating coil. Water at room temperature is acquired after condensation by a double layer condenser. Through this process, pure drinking water is achieved. Energy stored in the battery can be used at night and cloudy days.

Solar energy is used by this water purifier for the purification process. Water is purified through two stage purification processes, first filtering the water then boiling it. Filtering removes impurities from contaminated water [4] and then boiling kills existing living organisms [5]. Other mechanisms are temperature control mechanism and energy conversion and storage mechanism.

4.1 Filtering Mechanism

A water filtration column is used for filtering. This column contains layers of gravel, sand and activated charcoal [4]. Filtering removes oil layer, visible dirt, rust etc. Activated carbon removes tastes and odor-causing compounds [6].

4.2 Energy Conversion and Storage Mechanism

Solar energy is converted into electric energy by solar cell. Then this energy is stored in a battery which is used to boil water by converting electric energy into heat. An inverter is used to convert DC current to AC current and a controller is used to show the charging status of battery and restricts flow of electricity from battery to solar panel at night.

4.3 Boiling Mechanism

Boiling is the most certain way of killing all microorganisms. Water temperatures above 160˚ F (70˚ C) kill all pathogens within 30 minutes and above 185˚ F (85˚ C) within a few minutes. So in the time it takes for the water to reach the boiling point (212˚ F or 100˚ C from 160˚ F or 70˚ C), all pathogens will be killed, even at high altitude [7]. A heating coil is used to rise water temperature to 85˚C.

4.4 Temperature Control

In the solar water purifier, 85˚C water is found after boiling. A cooling mechanism should be used to make it suitable for human consuming. A double layer coil condenser is used to reduce temperature in this water purifier.

4.5 Cluster Function Structure for Solar Water Purifier

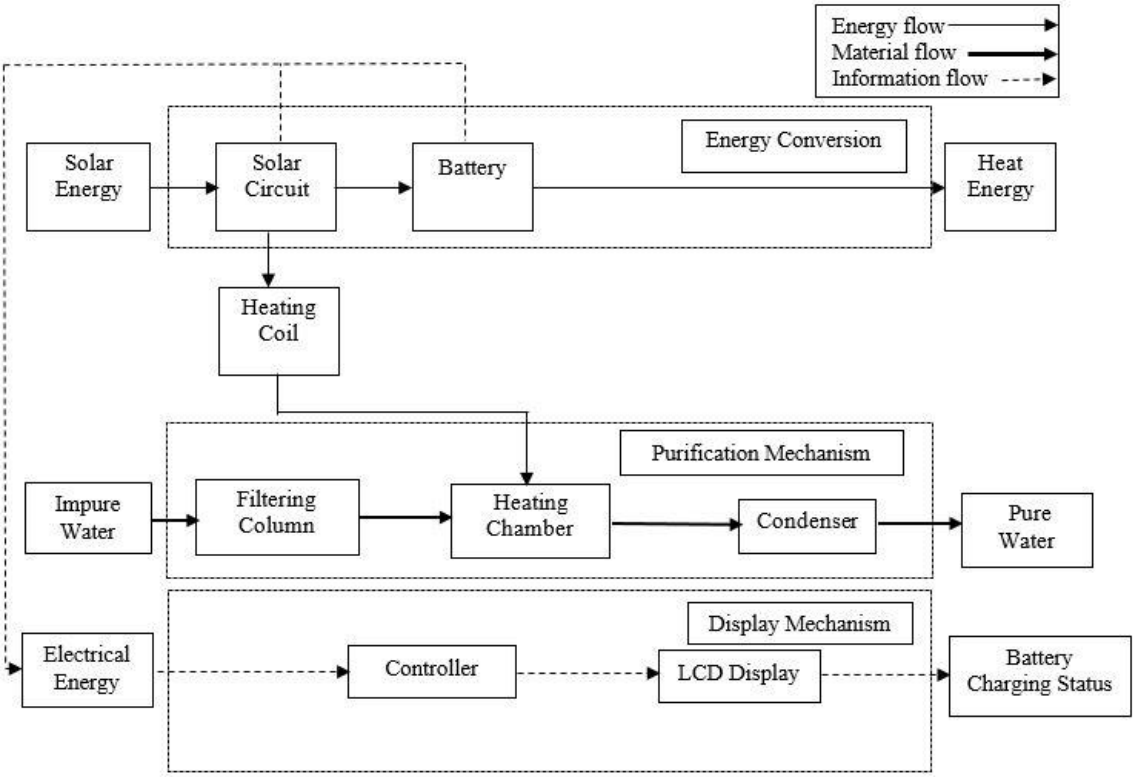


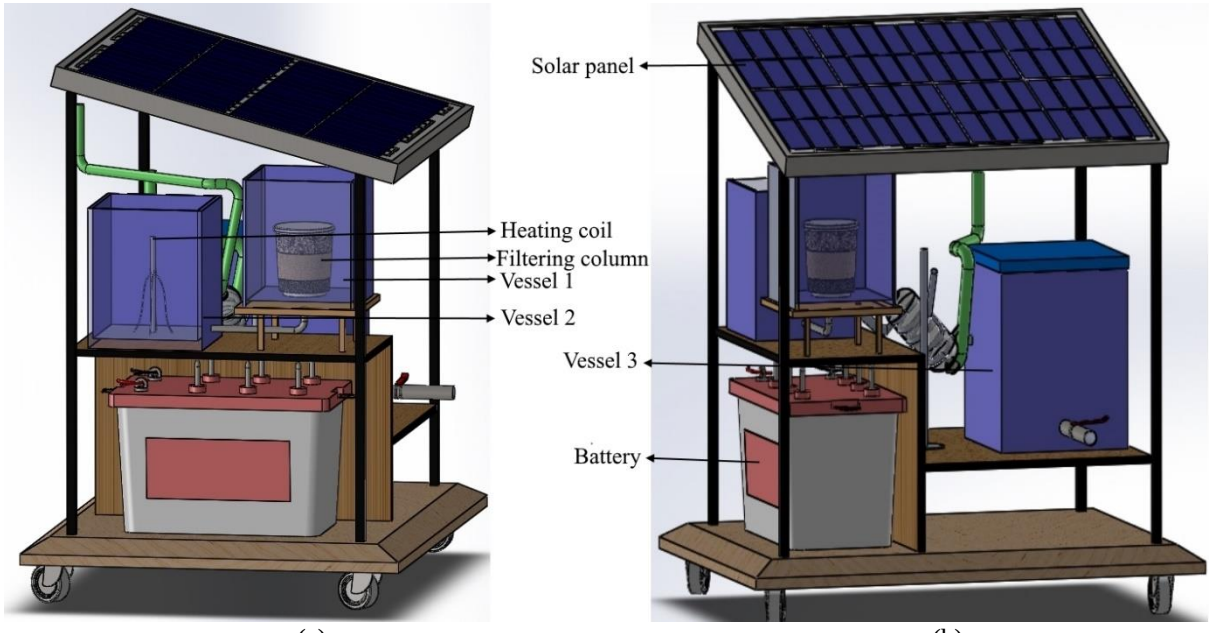
Figure 4. Cluster function of solar water purifier

Figure 4 shows cluster function of the product. Cluster function means mapping the whole product. Figure 4 shows interrelation among mechanisms and components of solar water purifier.

5. Construction

Construction of a product is the trickiest part of developig a product. This step includes decision associated with material, production process and specification selection. Some critical decisions are specification of solar panel, battery and heating coil. These information defines the charging time of battery by solar panel and time to increase water temperature by heating coil.

In solar water purifier, 150 W solar panel is used. Battery capaity is 40 AH and voltage is 12 V. A 200 watt AC heatig coil is used to boil water.



(a) (b)

Figure 5. Model of solar water purifier (a) LHS view (b) Front view

Final design of solar water purifier is done by SolidWorks and presented in figure 5.

In this water purifier, at first impure water is given in the first vessel which contains filtering column. After filtration, water flows to second vessel where water temperature is rised to 85˚C with a heating coil. Then, water at 85˚C flows through double layer condenser and temperature of output water is 35˚C-40˚C. Finally, water at room temperature is stored in third vessel from where pure drinking water can be consumed.

6. Energy Calculation

Energy calculation for capacity of solar panel and battery is shown in this paper to justify the design.
Battery capacity is measured in Amp Hours (e.g. 17AH). It is needed to be converted to Watt Hours by multiplying the AH figure by the battery voltage (e.g. 12V).

$$\text{Power available in battery (watt hours)} = X \text{ (Battery size in AH)} \times Y \text{ (Battery Voltage)} \quad (1)$$

By applying equation '(1)', using battery power 40 AH and voltage 12 V, power in battery is 480 WH.

Time to charge the battery fully = power available in battery (Watt Hours) / power of solar panel (Watt) (2)
So, from equation '(2)', time to charge the battery fully by using a 150 Watt solar panel is 3.2 Hours.
Water temperature is raised to 85 ˚ C from room temperature (30 ˚ C) to kill organisms. To obtain this temperature, rise for 5 liter (0.005 m^3) water requires a total heat input, Q_w, of 1149.5 kJ by applying equation '(3)'.

$$Q_w = (V_w)(\rho_w)(C_{p,w})(\Delta T_w) \quad (3)$$

Where V is the volume (m^3), ρ is the density (kg/m^3), Cp is the specific heat ($kJkg^{-1}K^{-1}$), and ΔT is the temperature rise (˚C or K). The subscript W denotes water. For water, ρ_w= 1000 kg/m^3 and $C_{p,w}$= 4.18 $kJkg^{-1}K^{-1}$.

$$\text{Time needed to rise water temperature, t (min)} = \frac{Q_w \times 1000}{Power\ of\ heating\ coil \times 60} \quad (4)$$

By using equation '(4)', time needed to rise water temperature using a 200 Watt AC heating coil, t is 95.79 min or 1 hr 35.79 min.
So, 1 hr 35.79 min is needed to rise temperature of 5 liter water to 85˚C.

7. Time Calculation

Time calculation is done for 5 liter water. Necessary data are summarized in table 1.

Table 1. Table for time of different mechanisms

Mechanism	Time needed (mins)
Filtration	40
Raising water temperature to 85˚C	96
Keeping 85˚C	15
Condensation	20
Total time	171

So, total time needed to purify 5 liter water by solar water purifier is 171 minutes or 2 hours 51 minutes. In the meantime, battery is charged again. So, the next cycle can take place.

8. Cost Calculation

Cost to produce a single piece solar water purifier is summarized in table 2.

Table 2. Table for price of different components

Component	Price (taka)
Solar Panel	9000
Solar Battery + Inverter + Controller	5000
Filtering Column	50
Heating Coil	250
Condenser	1200
Frame	300

Others	500
Total	16,300

Table 2 shows that, by using the proposed design in this paper, it only takes 16,300 taka and capable of providing more than 10 liter water per day using solar energy.

9. Comparison with Existing Solar Water Purifiers

One of the existing solar powered water purifiers is the Krystall, by SwissINSO Holdings, Inc., is able to produce up to 1,00,000 liters of purified water per day, the system is bulky, immobile [8]. H2All Mobile, by Trident Device system can purify up to 567 liters per day. The E3 Direct Solar Distillation System is able to produce 379 liters of clean water per day using only solar power. The solar purifier proposed in this paper can purify up to 15 liters of water per day for only $194. Their capacity vs. cost ratio reveals how economic the design is compared to the existing purifiers. The capacity and cost information of proposed and some existing solar water purifiers are summarized in table 3.

Table 3. Table for comparison of proposed and existing solar water purifiers

Solar Water Purifier	Capacity (Liter)	Cost ($)	Capacity/ Cost (Liter/$)
Proposed Solar water Purifier	15	194	0.077
Krystall	1,00,000	12,00,000	0.083
H2All Mobile	567	9,000	0.063
E3 Direct Solar Distillation System	379	25,000	0.015

The ratio of capacity and cost for proposed design of solar water purifier is larger than most existing solar purifiers. Besides, available water purification systems are not available for personal use. So, the proposed design of solar water purifier is economically beneficial and appropriate for socio-economic condition of Bangladesh.

10. Result and Discussion

It is observed that, the proposed design takes only 16,300 taka and very easy to maintain. It can purify 5 liter water within almost 1.5 hours. By using solar panel of required watt peak, charging of battery is very frequent. Almost 10-15 liter water can be purified everyday with this purifier, which is without any doubt better than other existing solar powered purifiers economically. It has wheels that provides mobility. It can be used at night or stormy days with the help of battery. Battery can be charged by electricity in case of consecutive stormy days.

11. Conclusion

This paper focuses on economic and simple design of solar water purifier. This product is totally ecofriendly. In addition to having no carbon dioxide emissions, the Solar Water Purifier doesn't produce any noise. Proper safety steps should be taken as heat and electricity are involved. Proper selection of materials and components will prevent electrical components from overheating and causing potential burn hazards.

Insufficiency of pure drinking water leads thousands of our people to danger every day. This product expected to mitigate drinking water crisis both in urban and rural area in Bangladesh. In rural areas, it can be done in big scale for better feasibility.

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