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Use of solar energy for disinfection of polluted water

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Abstract

Polluted water is causing serious health problems especially in the rural areas of Pakistan. People have limited access to safe water supply and many diseases like diarrhea and gastrointestinal diseases are transmitted by consumption of polluted water. We have investigated the potential of using solar energy to pasteurize water. Low cost indigenously available materials have been utilized to design and fabricate a solar box type pasteurizer having a capacity of three liters. The performance study of the pasteurizer was performed during the month of May 2008. The designed pasteurizer maintained water temperature in the range of 60 ^oC to 70 ^oC continuously for more than an hour which is enough for deactivation of coliform bacteria. The maximum water temperature on a clear sunny day was found to be 67 ^oC, corresponding to an ambient temperature of 40 ^oC. With the pasteurizer facing south, a very little repositioning was required. The low cost and operational simplicity of the pasteurizer make it affordable and usable. It is more useful in rural areas where other sources of energy like electricity and gas are not easily available.

Key words: Solar pasteurization, heating, disinfection, decontamination water

Introduction

Polluted drinking water is causing severe health problems in the remote areas of the subcontinent. Most recently, there have been reports of a large number of casualties due to gastro intestinal diseases caused by the contaminated and infected water. The procedures like boiling and filtration of water are costly, and require burning of fossil fuels. In majority of the rural areas where wood is still being used for cooking purposes, it is difficult to decontaminate water frequently. In the areas where plenty of sunshine is available, the solar energy may very effectively be utilized for the disinfection and decontamination of water. Unfortunately, very little work is done in our country to explore the possibility of using solar energy as a decontaminant.

Drinking water must be free of disease-causing organisms called pathogens. Pathogens can be viruses, protozoa or bacteria. Waterborne pathogens cause diseases such as hepatitis, giardiasis, and dysentery. To actually test water for specific harmful viruses, protozoa and bacteria is very time consuming and expensive. In addition, not all water laboratories are equipped and approved to do the testing required. Therefore, testing water for specific organisms is limited to investigating specific waterborne disease outbreaks. Coliform bacteria are used as water quality indicators for two main reasons:

1. Coliforms may be associated with the sources of pathogens contaminating water.
2. The analysis of drinking water for coliforms is relatively simple, economical and efficient.

In many parts of the world, work is already being carried to use solar energy for purposes other than cooking. David and Robert (1984) investigated the potential of using solar energy to pasteurize contaminated water. They heated water to a temperature of 65 ^oC in a box cooker. Razzak *et al.* (1985) carried out a direct method for obtaining pasteurization by using solar energy. They designed a concentrated solar pipe collector and obtained a temperature of 63 to 78 ^oC. Reddy and Verma (1986) studied the scope of using solar energy in pasteurization of milk. Joyce *et al.* (1996) reported the thermal effect of equatorial sunshine on water samples contaminated with high populations of coliforms. They investigated the feasibility of employing solar disinfection for highly turbid contaminated water. McGuigan *et al.* (1998) reported a series of experiments to identify and characterize the inactivation process in stored water, exposed to sunlight. Safapour and Metcalf (1999) described a simple and reliable method that could be used in developing countries to pasteurize milk and water with solar energy. Rijal and Fujioka (2001) evaluated the effectiveness of combining solar radiation and solar heating to disinfect contaminated water. Salih (2003) formulated a mathematical model to facilitate the prediction of solar disinfection by analyzing the effect of sunlight exposure. Walker *et al.* (2004) constructed solar disinfection system from commercially available packaging material. Duff and Hodgson (2005) designed, built and tested a passive solar water pasteurization system based on density difference flow principles. The system contained no valves and regulated the flow based on density difference. The system eliminated the boiling problems. Berney *et al.* (2006) investigated the

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effectiveness of solar disinfection method to pasteurize water for developing countries.

In the present work, we report the design and fabrication of a solar pasteurizer using low cost indigenous material. The efficiency of pasteurizer has been investigated under local environmental conditions. The major aim of the study was to find a design which is low cost and portable with the property that a temperature of 60 to 70 °C could be maintained over a large interval of time. The research work was carried out during the month of May in Faisalabad which is located at an altitude of 184.4 m from the sea-level. The Latitude and longitude are 31°26'N and 73°06'E, respectively.

Materials and Methods

The Solar Water Pasteurizer (SWP) was fabricated using standard appliance shipping cardboard (Walker *et al.*, 2004). The main insulating material of the SWP was multiple layered regular aluminum foil glued onto the cardboard (Ciochetti and Metcalf, 1984). The SWP consisted of an outer and an inner box with side insulators between them on two opposite sides. The shipping cardboards were cut into shapes of rectangles. The outer box having length of 75 cm and width of 38 cm was made 39.5 cm deep. The inner box was 52.5 cm long, 24 cm wide and 36 cm deep and was covered on both sides with aluminum foil. The inner box rested on squared cardboard pieces of length 8 cm, and 3.5 cm thick. The space between the two boxes was insulated using diagonally placed foiled side insulator made from cardboard pieces of length 11.3 cm and width 7 cm.

The pasteurizing chamber was 50.2 cm long, 23 cm wide and 35 cm deep. A piece of aluminum metal painted black with non toxic paint on the outside was placed at the bottom of the chamber. A removable glass window of thickness 5 mm was used to cover the pasteurizer. The top view of solar pasteurizer is shown in Figure 1. The water to be pasteurized was filled in an aluminum utensil pained black on the outside. The temperatures of the ambient air, inner space, base and water were recorded every ten minutes using mercury thermometers.

We tested the water for bacteria coliform before and after placing in the pasteurizer using membrane filter method (Ciocetti and Metcalf, 1984). The membrane filter method uses a fine porosity filter which can retain bacteria. The filter is placed in a Petri (culture) dish on a pad with growth enrichment media and is incubated for 24 hrs at 35 °C. Individual bacterial cells which collect on the filter grow into dome-shaped colonies. The coliform bacteria have a gold-green sheet, and are counted directly from the dish. To determine the temperatures at which coliforms would be inactivated, we performed nine separate experiments in which tap water was sampled for initial coliforms and was then heated on a hot plate (Rijal and Fujioka, 2001). Coliforms were removed when the tap water was heated to 60 -70°C.

Figure 1. Inner View of the Solar Pasteurizer. The inner box and outer box are clearly visible

The pasteurizer was placed in sunshine facing the geographical south from 8 am to 2 pm each day. Due to its geometrical construction a very little or no reorientation was required. Initially the direction of pasteurizer was adjusted towards south and then it remained in that position for the whole day.

Results and Discussion

The pasteurizer works on the principle of green house effect. The incoming solar radiation, after passing through the glass cover, is absorbed by the aluminum base of the inner box of pasteurizer. The temperature of the base rises and it emits the thermal radiation which has a longer wavelength. The glass is opaque to these longer waves and thus thermal radiation is trapped inside the box. However, some thermal energy is lost from the sides due to thermal conduction. In the present work we have used very simple type of side insulators which keep the radiation trapped inside the box.

We noted the time in which water temperature reached 62 °C which is the pasteurization temperature. The capacity of pasteurizer is three liters; we divided the water in one and two liter containers and checked the variation in rise time of the water temperature in both containers. The water temperature had a gradient from the upper to lower layer during the initial few hours, but afterwards it attained a uniform temperature. The graphical representation of variation in ambient, base and water temperatures for pasteurizer with side insulators is shown in Figure 2.

The efficiency of SWP was tested for nine samples of drinking water collected from different locations of Faisalabad city. In the first set of experiments, the pasteurizer was used without side insulators. Table 1 show that the maximum water temperature was 62 °C, achieved after three hours corresponding to an ambient temperature of 40°C. One liter of water was used in the container. In the next three experiments we used side insulator which resulted in a maximum temperature of 67 °C (Table 2). The difference of 5 °C resulted from the additional insulation provided by the side insulators. The solar pasteurizer has been found to be very effective, more efficient and cheaper as compared to the previously reported solar pasteurizers (Ciocetti and Metcalf, 1984; Berney *et al*., 2006). The quantity of water pasteurized was sufficient for a small family.

Table 1. Ambient, base, inner space, side and hot water temperature (°C) versus time without side insulators

Time	Ambient Temp. (°C)	Base Temp. (°C)	Side Temp. (°C)	Hot Water Temp. (°C)
11:00	38	54	45	40
11:10	38	60	50	40
11:20	38	64	50	41
11:30	38	65	50	42
11:40	38	68	50	44
11:50	38	70	57	47
12:00	38	70	58	48
12:10	38	70	60	50
12:20	38	70	62	50
12:30	39	69	64	52
12:40	39	68	66	53
12:50	39	68	68	55
01:00	39	68	68	57
01:10	39	69	68	58
01:20	39	69	68	59
01:30	39	69	67	60
01:40	40	70	69	61
01:50	40	70	70	62

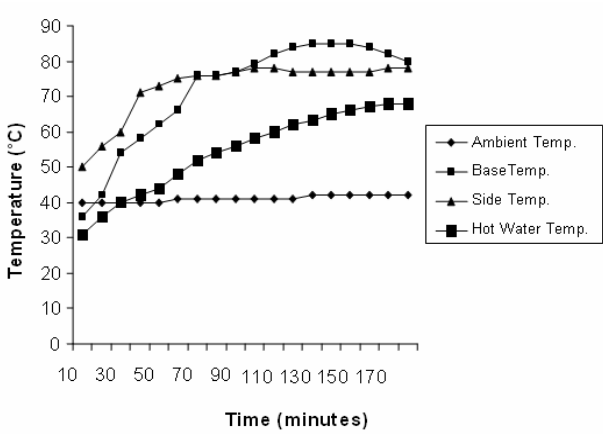

Figure 2. Variation in ambient, base, side and hot water temperatures Vs time (minutes) recorded with side insulator

Table 2. Ambient, base, inner space, side and hot water temperatures (°C) versus time recorded with side insulators

Time	Ambient Temp. (°C)	Base. Temp. (°C)	Side Temp. (°C)	Hot Water Temp. (°C)
10:50	38	40	62	38
11:00	38	54	71	42
11:10	38	57	74	44
11:20	39	60	76	48
11:30	39	62	77.5	50
11:40	39	64	79	52
11:50	40	66	79	56
12:00	40	70	80	58
12:10	40	76	81	60
12:20	40	78	81	62
12:30	40	80	81	64
12:40	40	80	81	64
12:50	40	80	79	64
01:00	40	81	79	65
01:10	40	82	79	66
01:20	40	82	79	66
01:30	40	82	79	66
01:40	40	82	79	66
01:50	40	83	79	67

The final water temperatures were a function of solar angle, weather conditions and heating time. Outside air temperature had no effect on the water temperature due to the proper insulations.

Conclusion

We may conclude that the solar pasteurization is simple, reliable, requires little maintenance and no electricity or energy besides the sun is needed. Pasteurization is not heavily impacted by the turbidity of water and is able to inactivate bacteria. Some of the suggested applications are the suitability for remote residential setting, rural health clinics and small schools.

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