Nat. Volatiles & Essent. Oils, 2021; 8(5): 3104-3110

Study On Performance Of Fresnel Lens For Thermal Efficiency And Microbial Reduction

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Abstract:

Solar disinfection (SODIS) is a well-established and well-proven method for producing safer drinking water. The goal of the project is to use Fresnel lenses to improve the solar disinfection process. By creating a quick temperature rise during the solar disinfection process, the Fresnel lens will speed up the rate of disinfection. A set up of Fresnel lens was constructed to carry out the disinfection process. Solar rays were focused by trial and error method onto the water sample for a fixed period through which thermal efficiency was determined. Parameters like fluid temperatures and collector area were used to find the thermal efficiency. Pasteurization temperature was found by determining the thermal efficiency. Water disinfection was done by conducting SODIS and Fresnel lens process. Standard plate count test was utilized to find out the bacteria present in the samples collected. The bacterial removal efficiency of Fresnel lens processes were determined and compared with SODIS process. This study provides a method to disinfect water utilizing only solar energy.

1. INTRODUCTION

Despite the many advanced technology developed by man in our present world, providing clean water to all humans remains a difficulty. Distillation is a simple procedure that may be used anywhere in the world to purify water. The only significant disadvantage is that it uses a lot of energy. Hence to overcome this drawback, solar energy could be used for water purification.

According to previous research, using a parabolic solar concentrator produces high concentration, which necessitates a larger field of view and a strong tracking mechanism. Concentrators using parabolic dishes become big and difficult to carry. Material changes, such as anodized aluminium sheets or aluminized plastic films for concentrators, are used to overcome this. Fresnel lenses concentrate solar energy, making it a cost-effective and environmentally beneficial energy source for water treatment. Properly termed a water lens, the device uses abundant resource - sunlight to heat and disinfect polluted water. The advantages of the Fresnel installation make it a serious alternative to some conventional techniques. The Fresnel lens water purifier's principal function is to turn unpurified water into drinkable water. Furthermore, because of its availability, abundance, and renewability, this proposal suggests the use of solar energy as the primary source of energy, as well as the use of an inverted Fresnel lens as a medium to collect the energy and direct it into the system. Fresnel lenses will boost the temperature more than normal lenses.

Mc Guigan et al. [6] described a series of studies to detect and characterise the inactivation process that occurs when Kenyan isolate of Escherichia coli contaminated severely in drinking water is stored in clear plastic bottles and then exposed to sunlight. The findings show that sun disinfection of drinking water is a cost-efficient and effective way for improving water quality, and that it could be especially useful in refugee camps in disaster zones.

Sales M T B F [9] focused on designing and build a Fresnel lens-based solar desalination system. The Fresnel lens was an effective solar concentrator made of acrylic plastic. Sun stills built of dark-colored glass bottles absorbed solar energy well. At room temperature, the polybutylene and polystyrene condenser system was effective in condensing the vapour. The quickest time for the salt water to vaporise was 293 seconds, and the lens's optimum angle of position was 36.42 °.

A Fresnel lens is a small lens that was initially designed for use in lighthouses but has since been employed in a variety of applications. Solar heating is one such scenario. The lens receives optimal sunlight and maintains a steady temperature of boiling water. In emergency situations where clean water is unavailable, the Fresnel lens water purification technology could be employed.

2. METHODOLOGY

Methodology of this project deals with experimental set up of SODIS & Fresnel lens process, how the thermal efficiency of Fresnel lens has been determined and the determination of microbial reduction in both SODIS and Fresnel lens process

2.1 SODIS Process

A bottle was filled with 500 ml of water, which was allowed to keep in the terrace for direct exposure of sunlight as such as in Fig.1. The initial temperature of the bottle was taken and then the temperature increase in every 15 minutes was also taken.

Figure.1 Set up of SODIS method

2.2 Fresnel lens disinfection process

A set up of Fresnel lens was constructed with acrylic sheet (concentric grooves) of size 297 x 210 mm. A lens holder made of wood was allowed to hold the lens. It was also fitted with screw adjustments for different elevation angle. Then glass beaker of 2l capacity was kept below the lens.

The lens was adjusted in trial and error method such that the reflected rays were allowed to focus in the water as shown in Fig.2.

Figure.2 Set up of Fresnel lens method

Lens holder was made of two stands and a frame. Lens was fixed inside the frame which is then connected with the stands. The lens was fixed inside such that the centroid of stand coincides with centroidal axis of Fresnel lens. For a particular time, by changing the capacity of water and the material properties of lens, the temperature difference in water was noted down. Table 1 shows the characteristics features of Fresnel lenses considered.

Table 1: Characteristics features of Fresnel lenses

Properties	**Focal length (mm)**	**Thickness (mm)**	**Groove pitch (mm)**
Lens 1	300	4	0.4
Lens 2	180	2	0.3

2.3 Calculation of thermal efficiency of Fresnel lens

Thermal efficiency determination was performed to determine when the lens was able to achieve pasteurization temperature and of which groove size is more efficient in transforming heat energy to the water. The thermal efficiency (η) of the lens is calculated by:

$$\eta = \frac{Qu/t}{AI}$$

A - collector area (m^2)
I - intensity of solar radiation (W/m^2)
Qu - Useful energy gain (MJ)

Useful energy gain (Qu) is the amount of energy utilised by the water to increase their temperature. It is determined by:

$$Qu = mC\,(T_f - T_i)$$

m - mass of the fluid (kg)
T_i - initial water temperature (°C)
T_f - final water temperature (°C)
C - Specific heat capacity of water (MJ/kg)

NOAA calculator gives an elevation angle (90-θ) when the date, time & location (Latitude and longitude) is given as an input. From elevation angle, zenith angle was calculated. The latitude and longitude of Coimbatore was given as 11.0168 °N & 76.9558°E respectively. The air mass (AM) can be determined by the following formula with the zenith angle θ

$$\mathrm{AM} = \frac{1}{\cos\theta}$$

The intensity of solar radiation (I) is given by

$$I = (1.353 \times 0.7)\mathrm{AM}^{0.678}$$

The collector area was taken as the surface area exposed to the sunlight, which is the area of Fresnel lens A = 297 x 210 mm.

2.4 Determination of Microbial reduction in SODIS and Fresnel lens process

To determine the microbes reduced in both SODIS and Fresnel lens process, the samples collected from both the processes have been examined under standard plate count test. Following procedures have been followed while testing the samples under standard plate count test. Initially 100 ml of Nutrient agar and 50 ml of buffer solution were taken.1ml of water sample to be used for plating was mixed with buffer solution by serial dilution. Then in a Petri dish, 10 to 15 ml of melted nutrient agar medium was added .The nutrient agar and the sample was thoroughly mixed. Then the plate was allowed to solidify and placed immediately in the incubator in an inverted position. Then plates were incubated at 37°C for 24 hours.

Colonies formed in the plates have been counted. Then by knowing the no of colonies formed in a plate and the dilution factor, the no of colony forming units (CFU) is calculated.

$$\text{No of CFU per ml} = \frac{\text{no of colonies formed per ml}}{\text{dilution factor}}$$

3. RESULTS AND DISCUSSIONS

3.1 Thermal efficiency determination

An amount of 250, 500 & 750 ml of water was taken in the beaker at different times and kept under the sunlight with Fresnel lens set up for 40 minutes. The temperature differences observed with 0.4 mm groove pitch Fresnel lens was noted down in Table 2.

Table 2: Temperature differences observed with Fresnel lens of 0.4 mm groove pitch

Day / Trial	Mass (ml)	T_i (^{0}C)	T_f (^{0}C)
1	250	26	49
2	500	26	45
3	750	27	37

The temperature differences observed by keeping water sample under Fresnel lens with 0.3 mm groove pitch were noted down in Table3.

Table 3: Temperature differences observed with Fresnel lens of 0.3 mm groove pitch

Day / Trial	Mass (ml)	T_i (^{0}C)	T_f (^{0}C)
1	250	26	51
2	500	28	42
3	750	27	38

Thermal efficiency was determined by calculating the useful energy gain and the intensity of solar radiation. The efficiency of Fresnel lens was calculated from the values determined and tabulated in Table 4.

The lens can increase the temperature efficiently for 500 ml than 250 ml & 750 ml. The pasteurization temperature is taken as 45^{0}C for Fresnel lens set up, since the efficiency of Fresnel lens 1 with 500 ml gives more efficiency (22.5 %).

Table 4: Efficiency of Fresnel lens

Day / Trial	I(kW/m^2)	Qu (kJ)	η (%)
1	0.962	24.09	17
2	1.008	33.52	22.5
3	0.987	31.42	21.4
4	1.332	26.18	13
5	1.324	35.61	17.95
6	1.315	34.56	17.6

3.2 Microbial effect reduction determination

Initially bore water was collected and was placed on Petri film to determine the microbes present in it. Then the same sample was allowed to keep under the Fresnel lens until it reaches its pasteurization temperature. Samples collected before treatment was considered as initial level. Samples treated with lens 1 and 2 were examined under standard plate count test and considered as final level 1 and 2. Results obtained from the standard plate count tests are tabulated in Table 5.

Table 5: Microbial test results observed for samples subjected to microbe removal using Fresnel lenses

Samples	Max limit Organisms / ml	Organisms observed / ml
Raw water	500	100
Treated with Lense 1	500	0
Treated with Lense 2	500	0

3.3 SODIS test results

Before the bottle was kept in SODIS process, the initial temperature of the water sample in the bottle was taken and then the temperature increase in every 15 minutes was also taken. Samples were taken at 15-minute intervals such as each sample at 0, 15, 30 & 45 minutes.

Samples obtained from SODIS process were tested under standard plate count test. CFU was determined and bacterial removal efficiency was calculated and tabulated in Table 6.

Table 6: Microbial test results observed for samples subjected to microbe removal using SODIS method

Time (min)	Temperature (°C)	Organisms / ml	Bacterial Removal efficiency (%)
0	23	320	-
15	26.5	200	37.5
30	28	100	68
45	30	100	68

3.4 Fresnel lens process results

Samples obtained from Fresnel lens process were tested under standard plate count test. Then CFU for each samples were determined and bacterial removal efficiency were calculated and tabulated in Table 7.

Table 7: Fresnel lens test results

Time (min)	Temperature (°C)	Organisms / ml	Bacterial Removal efficiency (%)
0	24	380	-
15	30	150	60.5
30	37	100	73
45	45	0	100

From Table 7, it is understood that when the Fresnel lens is used, there is a marginal increase in temperature of water compared with normal SODIS process in the same time.

4. CONCLUSION

Following conclusions have been drawn from this study:
The Fresnel lens with more groove pitch gives more efficiency. Hence for enhancing the microbial reduction, the Fresnel lens with more groove pitch is more suitable.
When the Fresnel lens set up was used, the pasteurization temperature achieved was 45°C.
The bacterial removal efficiency is 100 % in case of Fresnel lens, whereas in SODIS process, it is only 68% at the same time. Thus Fresnel lens enhances the normal SODIS process in disinfection.

ACKNOWLEDGEMENT

The authors wish to thank Dr. R. Rudramoorthy, the Principal, Dr. G. Sankarasubramanian, the Head of the Department of Civil Engineering, PSG College of Technology for providing the necessary facilities and guidance to complete the work successfully.

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