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Performance Analysis Of A Hybrid Water Purification System

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Abstract:

Fluoride contaminated water has become a major concern in many regions. In the present work a hybrid water purifier has been developed in order to enhance daily distillate and for delivery of fluoride free water. Two sources namely biomass/biogas and solar energy is used to heat and hence evaporate the water. Evaporated water vapour is condensed before it is collected as distillate. Performance of the water purifier was carried out at 5 (five) different water volumes (10, 15, 20, 25 and 30 litres) and at different quantities of fuel burning (2, 3, 3.5 and 5 kg) and solar radiation. Based on the experiment, it has been observed that maximum distillate of 5.5 litre has been observed in 4 hours for water volume of 10 litres. The performance of the hybrid is found to be enhanced with the incorporation of condenser.

Keywords: *Renewable; Solar; Biogas; Biomass; Fluoride; Potable*

Introduction

Fluoride contaminated drinking water is a severe problem in many parts of the world (including India) because of fluoride-related health hazards (severe anemia, stiff joints, painful and restricted movement, mottled teeth, muscle degeneration, kidney failure, and premature death to name a few), which are considered to be a major environmental problem today [1]. Fluoride in water is common in groundwater sources. Several methods are in practice to remove fluoride from drinking water. These include use of activated alumina, bone char, aluminum sulphate + lime mixes, ion exchange resins and reverse osmosis. Since ages, solar still, working on the principle of evaporation and condensation has also been identified to be an effective and affordable methodology of water purification [2]. From literature review, it is revealed that the majority of the work related to the improvement of solar still performance was tried in Middle East. In almost all the cases the output of the still has been found to be 1.4-3.5 l/m^2 with an average solar radiation of more than 800 W/m^2. This is more popular in the Middle East because of high solar radiation (above 800 W/m^2) and ambient temperature (above 40° C). Limited literature on improvement of solar still for removal of fluoride has been reported in India. The solar still so far installed in the various parts of the country is reported to be of very low efficiency. Based on the literature survey, various authors have tried to enhance the efficiency of the still by using foreign materials (inclusion of stone chips, jute clothes, sponge, water ball etc.) to capture heat and increase evaporation rate [2]. Various configurations such as hemispherical shape, conical shape etc. has also been tried by various authors [2]. However, the output of the still could not be increased as per requirement since the entire process is dependent of solar intensity. Hence, in order to increase the output of the still (both at individual or community level), in the present work a solar still based on solar and biogas/biomass based hybrid system is proposed.

Setup Description And Experimentation

Figure 1 shows a schematic of the solar and biogas/biomass based hybrid water purification system. The hybrid water purifier consists of two vessels containing water, one water tank to feed required quantity of water, one water level indicator, one condenser, one conical furnace and three distillate collection vessels. The water in the bigger vessel (located in the lower part) is heated by burning waste biomass and the water in the upper vessel is heated by using solar energy.

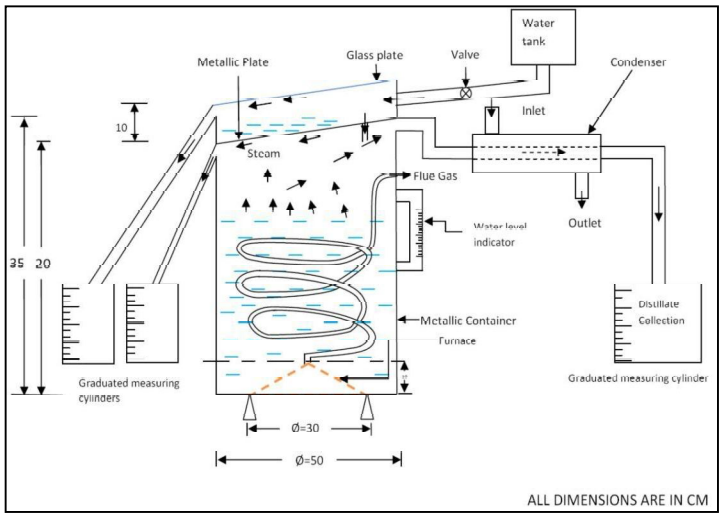

Figure1: Schematic of the solar and biogas/biomass based hybrid water purification system

The lower vessel is made of mild steel of internal diameter 50 cm and height of 20 cm and the amount of water required for each experiment is recorded in the water level indicator and it is controlled by a valve fitted with the overhead water tank. In each experiment initially, known quantity of biomass is burned in the furnace and the amount of distillate is recorded at different volumes of water. The heat carried by the flue gas by burning biomass is also utilized in heating water before it is released to the environment. The evaporated water generated by burning the waste biomass is collected in two different measuring cylinders. One of the measuring cylinders is connected at the metallic (aluminium) inclined surface, which is maintained at 20°C and the other is connected at the condenser exit. In the design, the volume of water occupied by the upper vessel is fixed at 1 liter. The upper vessel of the purifier is covered with glass at an inclination of 20°C. The distillate generated by using solar energy at the upper vessel is also collected. The amount of distillate generation is observed to be more at the condenser exit. The experiments are carried out at 4 (four) different quantities of biomass such as 2, 3, 3.5 and 5 kg and at 6 different water volumes such as 10, 15, 20, 25, 30, 35 litres.

Results And Discussion

Figure 2 shows the variation of volume of distillate generation with different volumes of water in the still, in the presence and absence of a condenser. The amount of biomass burned is same for both (3 kg). It is observed that with increase in water volume the distillate formation decreases.

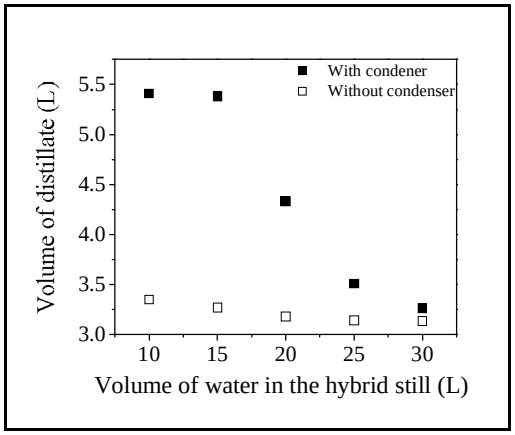

Figure 2: Performance of hybrid solar still in the presence and absence of condenser (fuel burned 3 kg)

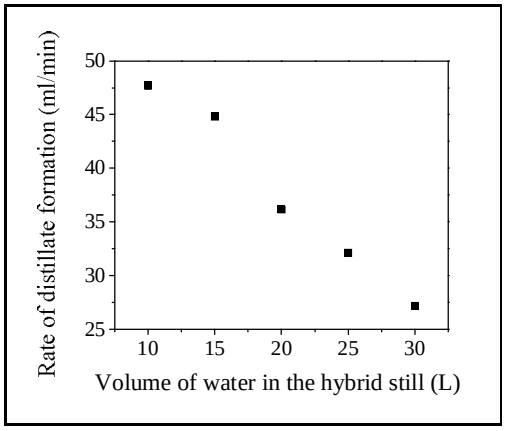

Figure 3: Rate of distillation (fuel burned 3 kg)

The yield is higher on integration of a condenser. The rate of distillation is observed to be volume dependent. Distillation rate decreases with increase in water volume in the still beyond 10 L (figure 3). The optimum yield of 5.5 L of distillate was obtained with a fuel quantity of 3 kg in the presence of the condenser (figure 2). Biomass utilization lower than 3 kg or above 3 kg lowers the yield as can be seen in figure 4.

To test the efficiency of solar still in removing fluoride from water, tests were conducted where fluorinated water (with known quantity of fluoride) was fed to the still and the quality of output water was monitored by chemical method (SPADNS). Table 1 reports the average of three different concentration of fluoride in the input water. The efficiency of the solar still to remove iron and total dissolved solids (TDS) from water was also tested and has been reported in the table.

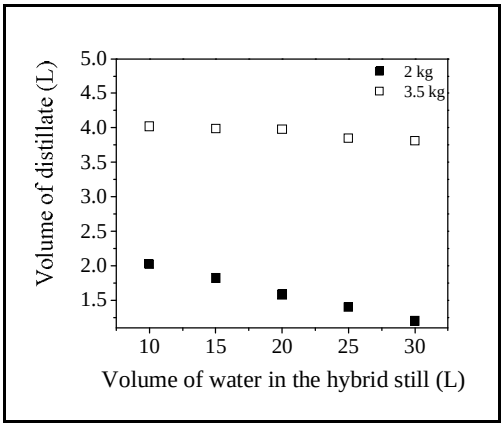

Figure 4: Performance of hybrid solar still with varying quantity of biomass (without condenser)

Sample type	Permitted level	Feed water	Still output water
Fluoride (mg/L)	1.5	6 60 600	<0.01 <0.01 <0.1
Iron (mg/L)	0.3	0.65	<0.05
TDS	---	36000	<1

Table 1 : Chemical test report of solar still water

Conclusion

This work reports a hybrid solar still based on solar energy and biomass energy. The system could efficiently generate fluoride free potable water. 5.5L of distillate could be generated in four hours from a feed of 10 L contaminated water and with the combined effect of biomass fuel and solar energy. The amount of waste biomass fuel required to achieve this distillate is 3 kg.

Acknowledgement

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Reference

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