Potential for water distillation by using solar energy in Malawi

A. Madhlopa [1,2] and C. Johnstone [1]

1. Energy Systems Research Unit, Department Of Mechanical Engineering, University of Strathclyde, 75 Montrose Street, Glasgow G1 1XJ, United Kingdom.

2. University of Malawi – The Polytechnic, P/Bag 303, Blantyre 3, Malawi.

Correspondance : Amos Madhlopa, E-mail: a.madhlopa@strath.ac.uk, Fax: +44 (0) 141 552 5105

Abstract

The potential for solar water distillation in Malawi has been modelled. Mean monthly global solar radiation (H) data from 19 sites spread all over the country was used to compute the mean monthly daily distillate productivity (M). Results show that H varies from 15.3 MJ m^{-2} to 27.8 MJ m^{-2} while M varies from 1.0 kg m^{-2} to 2.5 kg m^{-2}. Distillate productivity is high (up to 2.5 kg m^{-2}) during the dry season, in phase with the shortage of water supply. It appears that there is enormous potential for harnessing solar radiation to improve the quality of drinking water in the country.

Introduction

Clean water is essential for good health, which relates to socio-economic development. Nevertheless, safe drinking water is scarce, especial amongst rural communities in the developing countries due to financial and other constraints. Sophisticated technologies for water treatment are not affordable in such countries. Consequently, simple technologies for water disinfection and desalination are suitable.

It is important to choose a sustainable source of energy for improving the quality of drinking water. Renewable energy (RE) can provide a long-term sustainable solution. Previous studies have shown biomass to be the major source of energy in most developing countries (Kristoferson and Bokalders, 1991) but the large dependence on fuel wood is contributing to deforestation and other environmental problems. In contrast, solar energy is more sympathetic to the environment and available even in remote areas. Consequently, there is potential to exploit appropriate solar technologies for water treatment in developing countries.

Saito and El-Ghetany (2002) evaluated the efficiency of a pilot solar water disinfecting system in Japan. In their work, contaminated water (with 167, 000 Col/ml of coliform bacteria) was put in a cubic glass container and the container was placed in a box with double glazing on its top part. The system was exposed to solar radiation for 4 hrs on a sunny day. They found that all the coliform bacteria was eliminated after 3 hrs of exposure to sunlight. Craggs et al. (2004) studied the effect of sunlight on inactivation of *Escherichia coli* in waste water stabilization ponds in New Zealand. They found that sunlight action accounted for 75 % of the removal of *E. coli.* More recently, Méndez-Hermida et al. (2007) exposed water samples (contaminated with *Cryptosporidium parvum* and placed in transparent containers) to natural light in Southern Spain. It was observed that exposures of 8 and 12 hrs reduced *C. parvum* oocyst viability from 98 % to 11.7 % and 0.3 % respectively., However, simple disinfection reduces the harmful microorganisms but it does not reduce salinity and heavy metals (Hanson et al., 2004). In contrast, solar distillation reduces both chemical and biological contaminants. This can be achieved by using solar stills.

A basic solar still has a thin layer of water in a shallow basin, transparent cover over the water and a channel for collecting the distillate. Saline water in the basin is heated by solar radiation that passes through the transparent cover and is absorbed by the bottom part of the still basin. Vapour rises from the hot water and condenses when it gets into contact with the inner surface of the transparent cover. The condensate (clean water) is collected through a channel fitted along the lower edge of the transparent cover. According to Bouchekima et al. (1998), improvements in solar distillation technology makes it the ideal technology for remote isolated areas with water demands less than 50 m^3 per day.

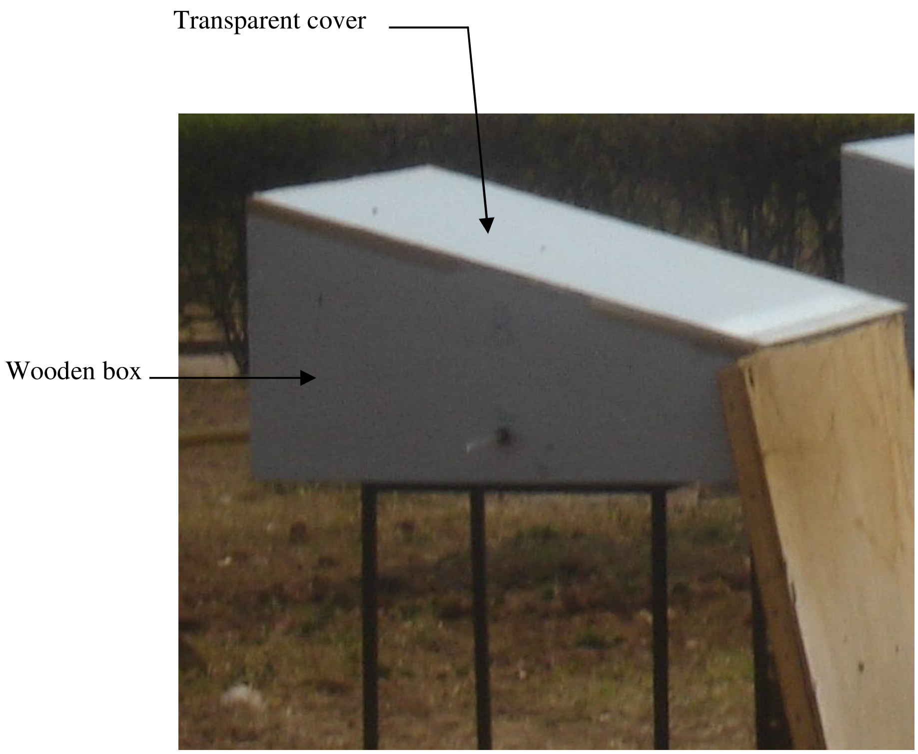
Objective of present study

The objective of this study was to assess the potential for solar water distillation in Malawi.

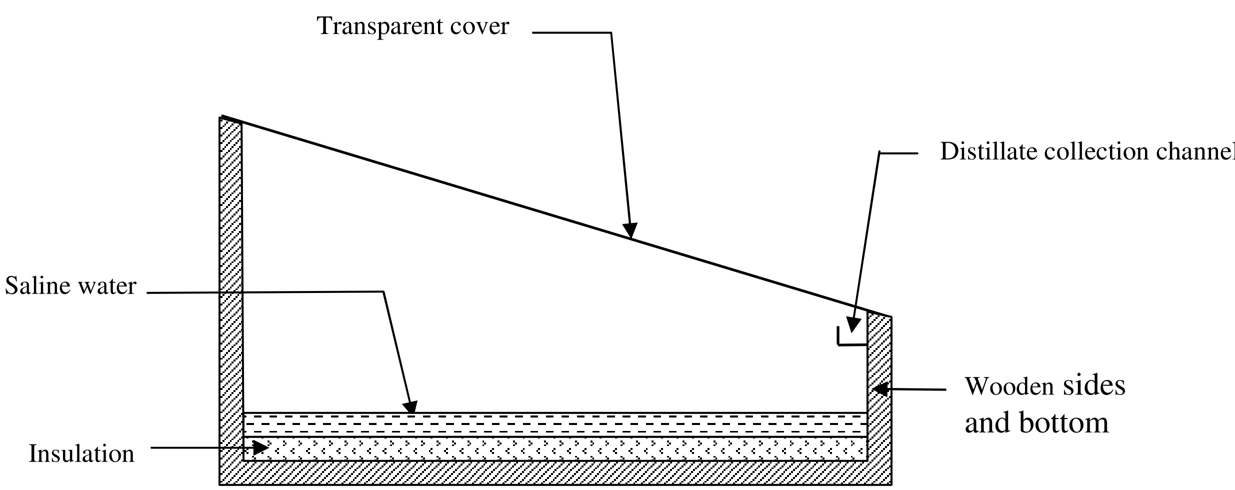
Study area

Malawi is a developing country in Africa located in the tropics between latitudes 9^o 22′ and 17^o 3′ S, and longitudes 33^o 40′ and 35^o 55′E. The country has a population of 12,884,000, with 83 % living in rural areas (World Health Organisation, 2006). The major sources of water in remote areas are shallow wells, boreholes, gravity-fed piped systems, springs, rivers and lakes. However, water sources are threatened by depletion and degradation mainly due to population increase, improper disposal of wastes and poor agricultural practices (Mumba et al., 1999; Lakudzala et al., 1999). Pritchard et al. (2007) studied 21 protected and 5 unprotected shallow wells during four different times of the year. They found that drinking water was significantly polluted with faecal waste. Over 50 % of 176 boreholes studied by Msonda et al (2007) had fluoride concentrations exceeding the World Health Organisation limit of 1.5 mg l^{-1}. Several other authors report on the low quality of drinking water, especially in rural areas of Malawi. World Health Organisation (2006) reports that 68 % and 98 % of the population in rural and urban areas respectively have access to improved drinking water sources.

In Malawi, water distillation is predominantly carried out using electrical heaters. The distillate is used in the chemical industry and laboratories where water of analytical grade is required. Distilled water is also needed in batteries for cars and photovoltaic systems that are used even in rural areas. Consumers of distilled water in rural areas find it difficult to source the product. Moreover, grid electricity is not available to power distillation equipment in such areas. So, an alternative source of energy is needed. Solar energy has been applied in vaporization of water in the production of salt from saline soils, in which the condensate was not recovered (Gondwe, 2004). Madhlopa (2006a) studied the performance of single-slope conventional still (Fig.1) under outdoor conditions. The system produced up to 4.8 kg m^{-2} per day under favorable climatic conditions. Nevertheless, very limited work has been done on solar distillation in Malawi.



(a)



(b)

Fig.1: a) Perspective view of a single-slope conventional solar still placed on a table during outdoor testing at the Malawi Polytechnic (15° 48′ S, 35° 02′ E), and b) cross-section of the still.

Methodology

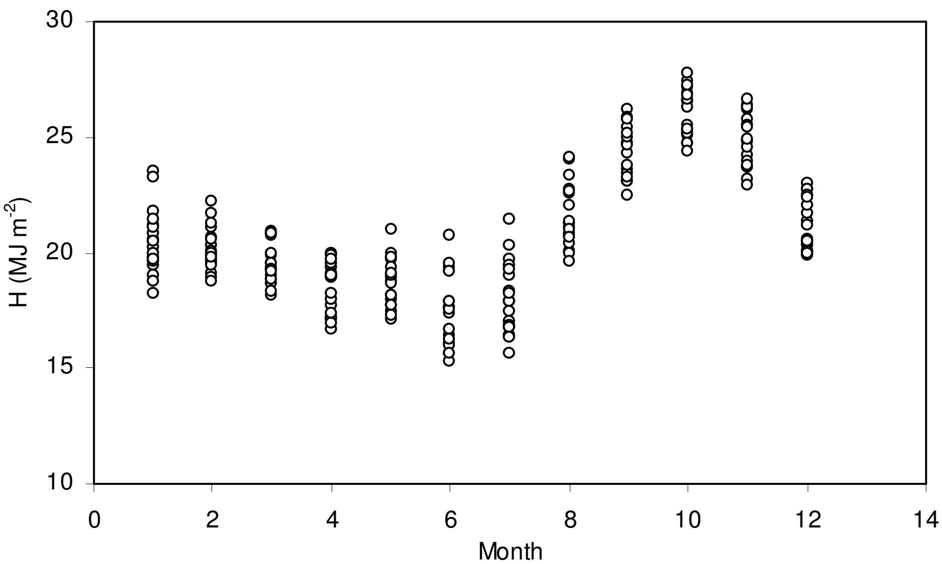
Mean monthly daily global solar radiation (H) captured at 19 different sites (spread all over the country) was obtained from the Department of Meteorological Services in Malawi. A simple linear model (Tiris et al., 1996) was used to compute the mean monthly daily productivity of distillate production (M).

$$M = a_o + a_1 H \qquad (1)$$

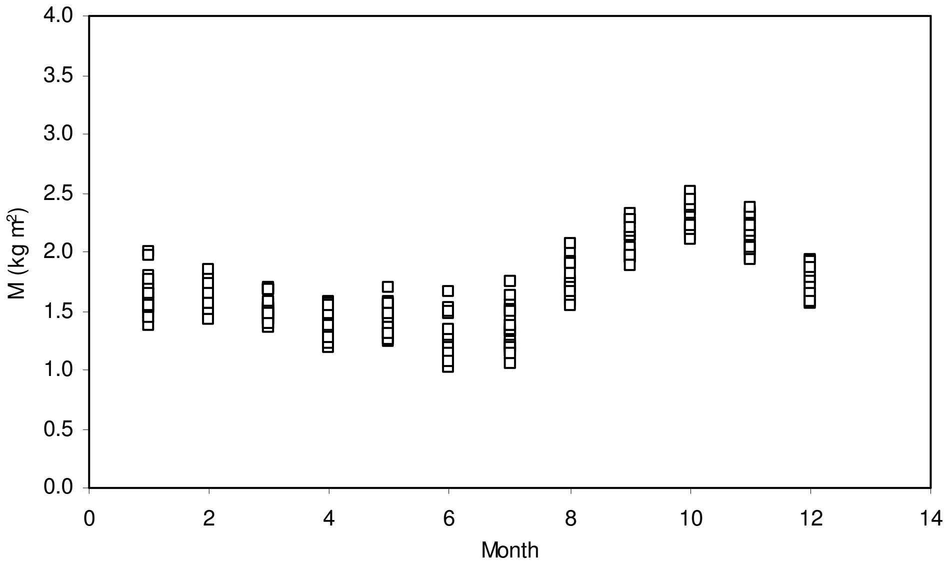
where a_o and a_1 are correlation coefficients evaluated using local experimental data obtained by testing a conventional solar still with a horizontal black-painted basin and saline water level of 4 cm (Madhlopa, 2006a). This correlation exhibited a root mean square error of 0.1 kg m^{-2}. It should be mentioned that distillate productivity is also affected by design, operational and environmental factors. Variations in these factors would therefore affect the performance the model.

Results

Figs. 2 and 3 show variations of mean monthly daily global solar radiation (H) and distillate production (M), respectively. H varies from 15.3 to 27.8 MJ m^{-2} while M varies from 1.0 to 2.5 kg m^{-2}.



(a)



(b)

Fig.2: Variation of mean monthly a) global solar radiation (H), and b) distillate productivity (M).

Discussion

Results show that H is highest in October and lowest in June. It is also observed that there is some variation in the spatial distribution of solar radiation (data points in a given month do not coincide for all the sites). These observations are consistent with previous findings. Zingano (2001) observed that lowlands have the highest values of global solar radiation while uplands have the lowest in Malawi. Diabate´ et al. (2004) found that the index of sky clearness was highest in September for the class II solar climate located in Malawi and Madagascar. More recently, Madhlopa (2006b) identified four seasonal classes (D1, D2, R1 and R2) based on two major climatic conditions (dry and wet seasons) of the country. Generally, solar radiation is most abundant during the dry season D2 (from August through November). The variation in the distribution of solar radiation in time and space indicates that distillate productivity would also vary with time and location.

It is pleasing to note that the mean monthly distillate output is generally high during the dry season, in phase with the problem of water supply in Malawi. The values of distillate productivity observed in the present study compare very well with findings (0.48 – 2.21 litre m^{-2}) of Tiris et al. (1996) for a conventional solar still with a black-painted basin liner and saline water level of 3 cm (1 litre of water ≈ 1 kg of water).

Conclusion

The potential for solar distillation at 19 sites in Malawi has been modeled. Results show that the mean monthly daily distillate productivity attains a peak level at all the sites during the dry season, commensurate with the daily global solar radiation. The distillate productivity is in phase with the supply of water. It appears that there is enormous potential for harnessing solar radiation to improve the quality of drinking water in the country.

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