

A plastic solar water purifier with high output

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Abstract

A solar water purifier is described which consists of a carefully designed black plastic sheet covered by a white glass window. The plastic is formed into an array of interconnected square cells which contain impure water. The selected material ensures that no plastic taste, colour or smell is transferred to the pure water output.

There are no filters, no electronics, no moving parts and cleaning is rarely needed. It is lightweight, cheap, strong, durable and can be used in any sunny location on Earth. Seawater input with 35,000 ppm of totally dissolved solids (TDS) is converted into potable water with a TDS of 1–2 ppm. Yields up to 9 l/m² day are obtained at 35 °C ambient or approximately 1000 W/m² of insolation.

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1. Introduction

The author visited Zimbabwe some years ago and observed the effect of polluted water and water-borne diseases on the health and life expectancy of young people in particular. There are of course many Third World countries with similar complications. After the visit, an attempt was made to outline the ideal parameters of a potentially useful device which would enable small family units to have access to their own, self-made, pure drinking water. No consideration was given to large, expensive to install, run and maintain, government instituted solutions such as the well-known reverse osmosis and flash distillation methods for the production of potable water. However, it was very quickly realised how difficult it would be to produce a portable, cheap to make and run device which would produce high-quality, potable water output from virtually any type of dirty input water such as sea, bore, effluent, urine, radioactive, arsenic contaminated, brackish etc.

2. Background and research objectives

Solar distillation of water has been studied in great detail by many workers (Howe and Tleimat, 1974; Tleimat and Howe, 1969; Fernandez and Chargo, 1990). Influenced by the results of their endeavours, it was ultimately decided to investigate more rigorously, the concept of the stepped solar tray system (Hastwell, 1995).

The easy conversion of readily available seawater into potable water was defined as the immediate objective. Ideally, any resulting device would be portable, lightweight, cheap to make, easy to operate, have a large output and be suited to small, individual family use in any sunny country around the World. It would of course be particularly useful in Third World countries. The resulting device became known as a “solar water purifier” and is described below.

3. Description of the solar water purifier

A black plastic sheet was vacuum formed onto an aluminium pattern which had been machined to the desired shape. The resultant plastic sheet consisted of a

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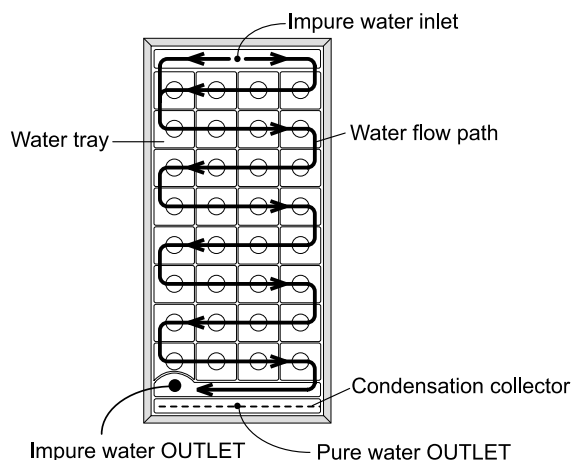


Fig. 1. Plan view of solar water purifier showing water flow path.

rectangular shaped array of shallow, square section trays which were interconnected by a series of weirs. Each individual tray was about 100 by 100 mm in cross-section and about 10 mm deep. The liquid holding capacity of each tray was thus about 100 ml. In all, the array consisted of 32 trays and suitable channels for distributing and collecting the impure and pure water outputs. Fig. 1 shows the arrangement used.

The black plastic absorber panel was covered by a toughened, white-glass window and sealed to it using the surface tension of the condensed water vapour produced during its escape from the trays of impure aqueous liquid.

A condensation collector in the pure water collection channel, redirected the sheeting flow of water from the underside of the cover glass into the channel itself.

The underside of the absorber panel was thermally insulated. The solar water purifier was then mounted in an aluminium frame for strength and shadow minimisation. Finally, the frame was fitted with folding legs so that overall, the system was inclined at 12.5° to the horizontal.

A handle for ease of carrying could be fitted if required. When using large banks of solar water purifiers to obtain large volumes of potable water, neither legs nor carry handles were needed (Fig. 2).

4. Principle of operation

Short wavelength, infra-red radiation ($0.7\text{--}2.5\ \mu$) from the sun is transmitted through the white glass, through the water and absorbed by the black plastic. The plastic re-radiates at long wavelengths ($8\text{--}10\ \mu$), hemispherically from each side of the plastic.



Fig. 2. Single unit solar water purifier.

On the non-water-side, an aluminium reflector transfers this long wavelength radiation back to the plastic where it is absorbed.

On the water-side of the plastic, the long wavelength radiation is directly absorbed by the water.

The water gets hot and vaporises. The water vapour drives out the air in the cavity between the glass and water surfaces.

The kinetic energy of the water vapour molecules on the glass cannot return to its source, and to conserve energy, the individual droplets coalesce forming a sheet of water which then runs down the underside of the glass window into a collection channel.

This “sheeting effect” can occur only if the system is considered to be an array of square section, short length heat pipes. Partial confirmation of this effect has been obtained by cooling the upper glass surface with a consequent cessation of the whole process. The theoretical study of this heat pipe effect is currently being investigated and will be published at a later date.

Simultaneously, the radiant flux transfer is being considered as a geometrical construction problem as shown in Fig. 3. Note that this diagram is not a heat flow (conduction, convection, radiation) diagram and is not to scale.

Tentative results indicate that the solar water purifier is quite an inefficient device mainly due to large losses in reflection from the glass window brought about by the well-known large variations in azimuth and elevation angles of the sun’s position throughout the year.

Careful consideration was given to the geometric design of the absorber panel particularly with respect to impure water flow rates, intermixing of the impure and pure water, convection reduction and shadow minimisation within each of the 32 trays of the panel. In addition, the location and material of the outlets were found to seriously influence the quality of the pure water

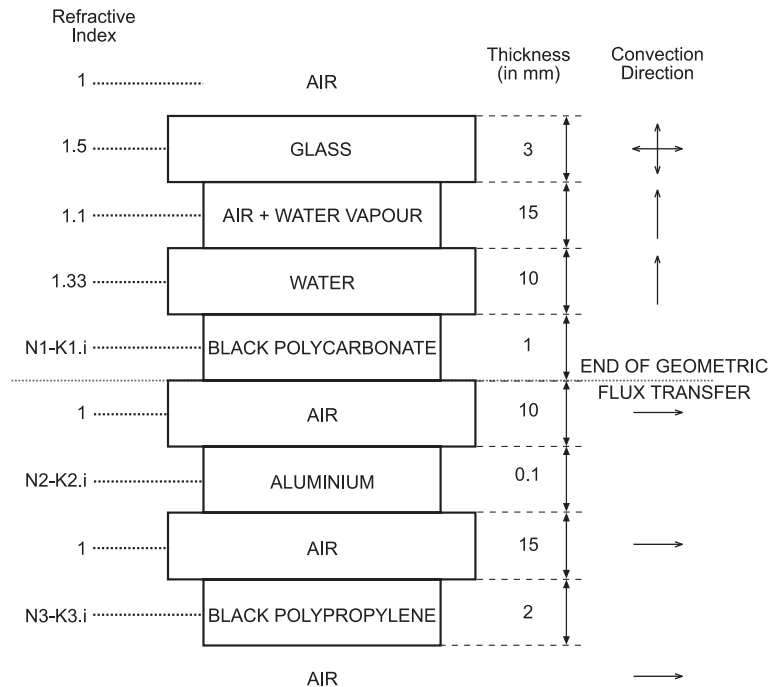


Fig. 3. Geometrical construction of the solar water purifier.

output. The general layout of the Solar Water Purifier is shown in Fig. 4.

The near infrared radiation ($0.7\text{--}2.5\ \mu$) emitted by the sun and transmitted by the glass effectively heats the impure water and initiates the production of water vapour for the heat pipe effect to commence.

The ultraviolet radiation ($0.34\text{--}0.40\ \mu$) combined with prolonged exposure times proves to be extremely

effective for the high killing rates (measured at $>99.99\%$) of many commonly occurring bacteria, such as, *Salmonella* spp., *Shigella* spp., *Escherichia coli*, *Campylobacter coli*, etc.

A further advantage of the design geometry enables good use to be made of the inability of bacteria to cross over the water vapour barrier above each tray of impure water.

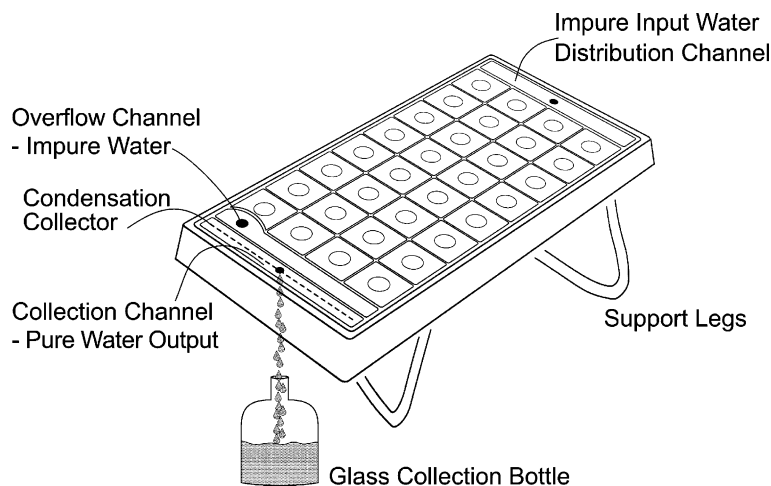


Fig. 4. General layout of the solar water purifier.

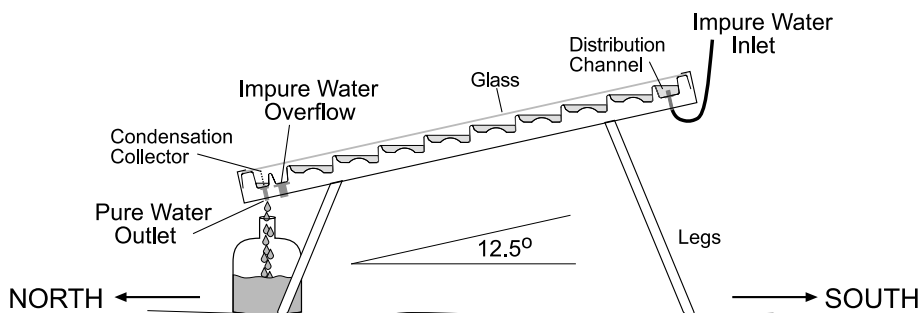


Fig. 5. Layout and orientation of the solar water purifier in the southern hemisphere.

4.1. Positioning the solar water purifier

In the southern hemisphere the purifier should be oriented with the input end facing south as shown in Fig. 5, while in the northern hemisphere the north and south positions must be interchanged. The purifier is facing in the north–south direction when the purifier shadow is aligned along the purifier itself around 12 o'clock noon at your location, as shown in Fig. 6. This is the orientation to use if you want to operate the purifier in a fixed, stationary position.

4.2. Maximising output from the solar water purifier

The output of the purifier is maximised when it is correctly positioned with respect to the direction of the sun. The simple alignment procedure shown in Fig. 6 can be used at any time of the day to produce the maximum output of pure water. For example, if you rotate the purifier every 30 min. or so throughout the day so that its shadow is underneath itself then the overall output for that day will increase by about 30%.

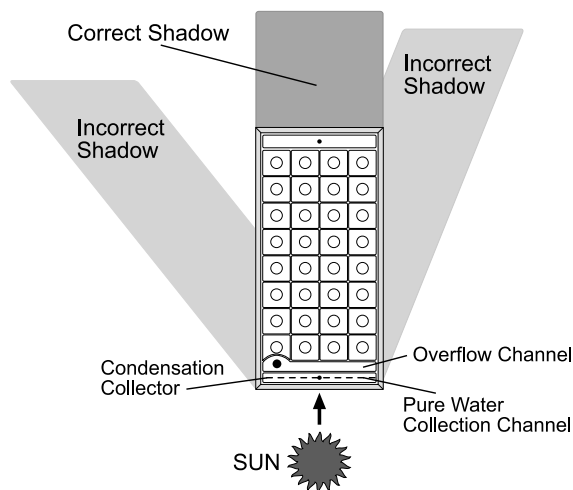


Fig. 6. Aligning the solar water purifier to the sun.

Effectively you are tracking the sun. However, if you move the panel in this way then you must be very careful to keep the panel level and avoid slopping any impure water into the pure water outlet channel.

The purifier must be adjusted to the horizontal so that the water level at both ends of the input channel is the same height, as shown by the symbol H in Fig. 7. To avoid the possibility of impure input water overflowing into the pure water outlet, the input water should be fed slowly into the input channel until all the trays are full and water is just starting to flow out of the impure water outlet. 4.5 l of input water is sufficient to fill the purifier unit. To maintain the purity of the output, a clean glass bottle rather than plastic should be used to collect the pure water output.

The purifier can be operated in two modes: in 'Static mode' where the initial fill of 4.5 l is not replenished throughout the day, or in 'Dynamic mode' as shown in Fig. 8 where impure water from a reservoir drip feeds continuously through the purifier at a rate of about 10–15 l per day.

4.3. Maintenance of the solar water purifier

The major maintenance activity required to ensure that the solar water purifier continues to provide pure water output is cleaning.

When the purifier is operated in the Dynamic mode, the dissolved solids in the water continuously flow through the purifier into the overflow channel. Virtually none of the dissolved solids settle out in the trays and therefore the purifier rarely needs cleaning.

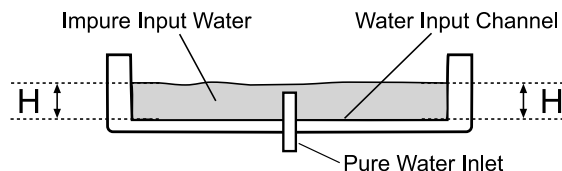


Fig. 7. Leveling the purifier.

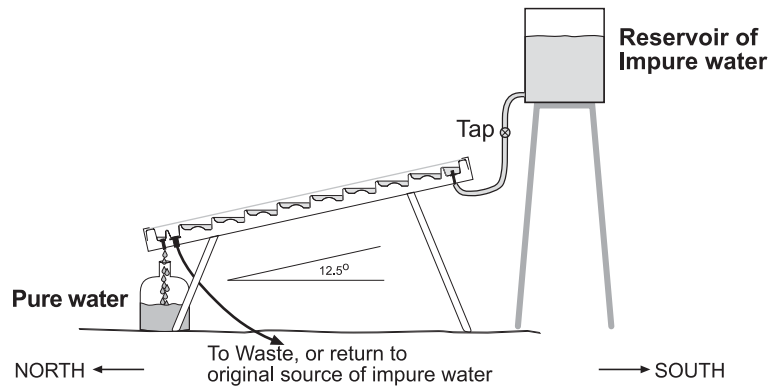


Fig. 8. Dynamic mode operation in the southern hemisphere.

If the purifier is operated in the Static mode, then the solids which were in solution are deposited on the surface of each tray and further exposure to the sun ultimately produces a coloured hardened deposit that is undesirable. This deposit can readily be removed by cleaning with a dilute acid solution such as citric acid (or lemon juice) or oxalic acid, which are not harmful.

In either operating mode, the outer surface of the glass must be cleaned regularly to remove dust and any other contamination to allow maximum transmission of the sun's rays through the glass and into the water.

Sometimes, when re-commencing operation after an extended period without use, a mass of small droplets may form on the underside of the glass inside the purifier. Visually the glass will appear to be quite white, because these small bubbles reflect the sun's visible and near infrared radiation and totally prevent the water from heating up, thus lowering considerably the efficiency of the purifier. This occurs because of a build up of a very thin, almost molecular layer on the glass surface which prevents wetting taking place. This problem can be overcome by removing the glass, cleaning it thoroughly and replacing it in its original position.

5. Conclusion and the future

A solar water purifier has been designed, made and tested successfully. It will readily convert impure water such as bore, sea, brackish, urine, radioactive, arsenic contaminated, effluent etc into pure drinking water with a TDS content of 1–2 ppm. Insolation values of about 1000 W/m² result in outputs of about 9 l/m² day at Adelaide, South Australia, Latitude 35° South. It is rugged, lightweight, portable and suitable for remote outback or Third World countries.

There are two types of output water:

- (i) pure water,
- (ii) impure water with an increase in concentration of whatever was dissolved or suspended in the original impure water.

The present solar water purifier has a water surface area of 0.33 m². It is proposed to increase this to 0.5 m² in the near future. Large arrays of these purifiers can be assembled for the production of large volumes of water.

Acknowledgements

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