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Editors:
D S Mansell, D F Stewart & B W Walker

for the Organising Committee:
R J Fuller
D S Mansell
A G Marjoram
C Scollay
D F Stewart
B W Walker

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SOLAR POWERED UV WATER DISINFECTION FOR SMALL WATER SUPPLY SYSTEMS

W L James
Murdoch University Energy Research Institute
Murdoch University

BACKGROUND

The Murdoch University Energy Research Institute (MUERI) has been investigating some of the water supply problems affecting very small and remote aboriginal groups.

The initial work has been dedicated to investigating the means of obtaining water from bores, utilising simple low cost, low maintenance solar powered water pumping equipment. Progress has been significant, with a number of pumps being tested and suitable equipment developed to provide satisfactory water supplies for transient camps and homeland settlements.

Some of the results of the above investigation reveal the following:

1. There are emerging outstations where the residence is not permanent. These are generally transit camps within the owners' traditional lands and could be inhabited for periods of months.

   Water is required for these groups for drinking, hand washing and cooking. A minimum requirement of 10 litres/person/day could be quite acceptable. The groups vary in size but generally are under 30 people. A water supply system of 300 to 500 litres per day with three days storage capacity could be adequate.

2. Established outstations have a population of under 50 people, with peaks at times of 120. Here, a larger water supply system is justified to provide water for drinking, handwashing, cooking, clothes washing, ablutions and toilets. Water requirements for the above should range in the 80 to 150 litres/person/day. This compares well with Perth's in house water usage of 118 litres/person/day [1].

WATER QUALITY

The next issue is that of the quality of the water. There are three aspects to water quality; ie, physical, chemical and bacteriological.

The physical properties relate to colour, taste and odour, turbidity and pH. These are parameters which the potential user can easily assess and can generally make a safe decision on whether or not to drink.

The chemical properties relate to total dissolved solids (TDS) such as calcium, chloride, copper, sulphates, sodium, zinc, nitrate, fluoride and trace elements. Some of these components can be easily identified by taste or odour. The effects of drinking chemically contaminated water...
generally occur over a longer term with damaging effects to kidneys and gastric system. Although most of these components in 'reasonable' doses are not damaging to adults, they can be dangerous to bottle fed infants, particularly sodium and nitrate. The presence of fluoride may have beneficial effects on teeth at low levels and harmful dental and skeletal effects at high levels.

The bacteriological properties relate to the presence of coliform and E.coliform bacteria which give an indication of the level of contamination of water by organisms found in human and animal wastes. The contamination of water by wastes creates conditions whereby viruses and bacteria create health hazards to humans when ingesting or utilising the contaminated water. The effects are generally immediate, reflecting themselves in chronic diarrhoea, intestinal parasites, to major epidemics resulting in death. The level of bacteriological contamination must not be compromised. The use of contaminated water for washing food will generally result in contaminated food, which once ingested will produce, similar deleterious results [2].

METHODS OF WATER TREATMENT

The most common treatment for bacteriological contamination is chlorination and storage, boiling and exposure to ultraviolet light.

Chlorination has been the most commonly used method of disinfection. There are several variations to the methods of chlorination but they require the replacement of consumables, some of which are affected by the high temperature and high humidity experienced in some outback areas. The system needs maintenance and control, two very scarce commodities in the outback [3]. The chlorination system has also a problem of acceptance. Many aboriginal communities object strongly to its use, some even believing that chlorinated water is the cause of illness [3].

The primary action of ultraviolet light in killing micro organisms is direct damage to the cellular nucleic acids. The DNA is prevented from replicating and it results in the death of the cell.

Ultraviolet light is a shortwave component of the solar spectrum (Figure 1) thus the exposure of water to solar radiation for the necessary period of time can reduce significantly the level of bacterial contamination. This is, in fact, an effective treatment for drinking water in some developing countries.

Ultraviolet radiation covers the range from 100-400 nanometres (nm) as indicated in Figure 2.
Figure 1:
Spectral Irradiance Curves for Direct Sunlight extraterrestrially and at sea level with the sun directly overhead. Shaded areas indicate absorption due to atmospheric constituents, mainly H₂O, CO₂ and O₃. Wavelengths potentially utilised in different solar energy applications are indicated at the top.

Figure 2: Ultraviolet Radiation Spectrum

Ultraviolet light disinfection systems use low pressure mercury vapour lamps which generate shortwave radiation in the region of 253.7nm. This radiation is generally considered effective in destroying micro organisms, including bacteria, protozoa, viruses, moulds, yeasts, fungi, nematode eggs and algae, although maximum ultraviolet absorption is assumed to occur at 265nm.
The use of ultraviolet light disinfection in respect to drinking water applications is generally required to conform with a statement issued by the United States Public Health Service during 1966 which indicated an ultraviolet light dosage requirement of 1600 microwatt seconds per square centimetre to provide pathogen free water at point of use. A typical layout for the installation of an ultraviolet light disinfection unit is indicated in Figure 3.

![Figure 3: Drinking Water Disinfection Schematic Layout](image)

Electric powered UV light disinfection units have been in operation for several years now and are being considered by the water authorities for use in outback applications around Australia. Essentially the ultraviolet light system involves the flow of water through clear tubes and past ultraviolet light transmitting lamps generally as shown in Figure 4.

![Figure 4: Ultraviolet Light Disinfection Plant Layout](image)

The systems are generally designed to provide a fairly large ultraviolet dose, 20,000 to 30,000 microwatt seconds per square centimetre with most common microorganisms being destroyed with a dosage of between 2,000 to 10,000 microwatt seconds per square centimetre.
Some of the advantages of an ultraviolet disinfection system for use in outback areas are:

1. There is no need for operator attendance
2. Consumables are replaced only once per annum (light tubes)
3. There is no alteration to taste, odour or colour
4. Operational costs are reduced compared to chlorination
5. The units can be solar powered

Some of the disadvantages are:

1. There is a higher initial capital cost
2. Effectiveness is reduced where iron or turbidity is present
3. The unit does not provide continuous protection against recontamination in the reticulation

In view of the above characteristics the Water Authority of Western Australia has installed several UV plants at remote aboriginal communities where power is available. The results [3] appear to be promising.

TRANSPORTABLE WATER SUPPLY AND DISINFECTION UNIT

A portable water supply and disinfection unit was designed by the Water Authority of Western Australia for community transient camps, this time powered by solar energy. The system is designed to pump water from a bore, store it and disinfect it, and is all powered exclusively by photovoltaic panels (see Figure 5).

The system consists of:

1. An air lift (compressor powered) bore hole pump
2. An 11m" tank mounted on removable legs
3. A dc powered UV plant
4. A UV recirculating pump
5. Solar panels mounted on the tank

The whole unit can be mounted on the back of an eight tonne truck. It carries its own lifting jacks to load and off-load the tank.

The system capacity is determined by the depth of the bore hole, for a 15 to 20 metre deep water table the system can produce approximately 2,000 litres of drinking water per day as shown in Table 1.
Table 1

<table>
<thead>
<tr>
<th></th>
<th>PV Input</th>
<th>Water Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Watts</td>
<td>Litres/Day</td>
</tr>
<tr>
<td>Bore Pump</td>
<td>135</td>
<td>2,000*</td>
</tr>
<tr>
<td>Recirculating Pum</td>
<td>90</td>
<td>4,000</td>
</tr>
<tr>
<td>UV Plant</td>
<td>45</td>
<td>4,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>270</td>
<td>2,000*</td>
</tr>
</tbody>
</table>

* Daily output is limited to bore pump output

Figure 5: Transportable Water Supply and disinfection Unit
In conventional designs it is recommended to install the UV plant at the point of distribution, in this case the tank outlet. However, an uncontrolled use of water would require a very large unit and thus relatively large amounts of electric energy, solar panels and battery storage.

To achieve complete disinfection the UV plant would have to operate 24 hours/day so that at the opening of any tap at any time of the day there is total protection. This mode of operation will require very large numbers of solar panels and batteries. A compromise would be to use a solenoid valve that would start the UV plant any time water is drawn off by detecting a flow or pressure signal. This would significantly reduce the solar and battery requirement but the complexity is increased and the reliability decreased.

The other problem is that the residual water in the UV plant may be contaminated and may escape treatment as there will be some time lapse between opening a tap and UV plant start up.

The systems listed above require electric storage. Although battery technology is improving it still requires some degree of maintenance, it is expensive and has generally a reduced life expectancy; ie, under five years for lead-acid batteries. Other batteries with longer lives (such as nickel cadmium) are generally four to five times more expensive.

OTHER OPTIONS

Whilst we are dealing with water, it is logical to consider it as a means of storage. If we can store treated water this means that we can do away with electric batteries, it is cheaper, has a longer life and can be serviced locally if needed.

Two options were considered when using water storage:

- Treatment of the water before it enters the tank
- Treatment of the water whilst it is in the tank

TREATMENT OF THE WATER BEFORE IT EN特斯 THE TANK

The UV plant would be installed at the pump outlet. This will work all right, provided that the tank is secure and the lid is kept on. However, as there is no supervision on the system for very extended periods, it is not possible to guarantee this. Generally dead birds are a frequent source of contamination for open tanks.

This solution is the one of lowest cost if a hermetic tank could be guaranteed.

TREATMENT OF THE WATER WHILST IT IS IN THE TANK

This system would recirculate the water from the bottom to the top of the tank and through the UV plant, utilising a small recirculating pump. The recirculating flow rate is double that of the bore hole pump.

This system makes full use of the UV treatment as it operates every day regardless of whether the bore hole unit is pumping or not (ie, whether or not there is a full tank).
This system appeared the most adequate for this application. As the water supply system is meant for a transient camp there could be extended periods where no water would be pumped or drawn and the chances of contamination could be high. With the UV plant working every day during daylight hours the water has a good opportunity to be well disinfected.

The system is slightly more expensive as it requires a second pump and solar panels to power it. However, as it pumps against little or no head the energy consumed is quite small.

Such a system was designed and built by the Water Authority of Western Australia and trialled at MUERI.

SYSTEM TEST

The tank was artificially contaminated with a strong bacteriological cocktail provided by the State Health Laboratory Services. The initial count for coliforms and E. coliiform was greater than 100,000/ml with a decrease to 20,000 in five days for 11,000 litres. Disinfection continued, but unfortunately no readings were available for a period of 45 days, after which a reading was taken with a total count of 162/ml which is a safe drinking level.

A second contamination was implemented on the 29th March 1989, this time not so severe. After one week of operation the count dropped to 16/ml. The solar radiation for that week was patchy, with four clear days and three with 30 to 40% cloud cover.

Due to an urgent requirement for the system by a community in the desert no further tests were carried out.

Although the tests were not conclusive they proved that the system works and that it provides quite a reasonable degree of protection using a reliable system at reasonable costs. Because the system is transportable the degree of utilisation of the unit with semi-nomadic communities (as aboriginal communities are) is high and therefore so is the degree of cost effectiveness.

The system can be designed to be smaller or larger, depending on the circumstances of use and the size of the group or community.

RETROFITTING STANDBY POWER TO AN EXISTING UV TREATMENT PLANT POWERED BY A DIESEL GENERATOR SET

The larger remote communities are generally powered by a diesel generator set which operates 24 hours/day. In these cases there is a water reticulation system and the water demands can be substantial.

These systems could already have a UV system installed at the storage tank outlet or at the main distribution point. If the power supply is disrupted (some of them very often) then the risk of contamination is high. The longer the disruption period the larger the risk.

To prevent infection during this period, the diesel plant could have an automatic stand by for the UV plant. This may consist of a battery charger, a battery bank and an inverter, as set out in Figure 6. During normal operation of the diesel generator the battery charger is connected to the mains and keeps the batteries fully charged. As soon as there is a power interruption the batteries
supply the power automatically to the UV unit via an inverter. It is important that the power is supplied only to the UV unit during diesel failure.

This connection should be hard wired with proper interruption circuits approved by the electrical authorities. The danger here is that if this is not done properly the grid could be electrified via the inverter when the diesel is off. Anyone working or interfering with the wiring, assuming that the power is off because the generator is off, could be subjected to a very dangerous situation. Another reason to have the inverter connected to the UV plant only is that the batteries need to be sized only to power the UV plant and this therefore minimises costs.

![Diagram of Automatic Standby for UV Plant]

Figure 6: Automatic Standby for UV Plant

If the diesel is to be disconnected for periods in excess of 12 to 20 hours it might be prudent to have a second engine or solar panels as a standby, also powering the batteries.

The important aspect is to keep the UV plant powered continuously, 24 hours/day. If contaminated water from the tank is allowed into the reticulation system it will infect it, and even when the power is restored the disinfected water will be recontaminated by the reticulation. A chlorination disinfection would then be required.

Such a system has been built and installed for a community in the Kimberleys, Western Australia, where the diesel generator stoppages occurred generally once per week. A conventional 240V UV water disinfection unit had been installed for some time, but right after each diesel generator stoppage people, particularly children, would get ill due to water contamination.

Since the installation of the battery/inverter and solar standby system in May 1989 the UV plant has operated continuously, thus ensuring a safe water supply system.
SMALL TRANSPORTABLE UV SYSTEM

A further development from the large transportable UV system described earlier is a smaller unit mounted on a trailer, incorporating the solar panels, 900 litres storage tank, pump, UV units and hoses. This unit is quite versatile as it can be towed and parked by a car with a towbar (see Figure 6).

The unit is now commercially available complete with trailer or in a kit form without the tank and trailer.

![FIGURE 6](image)

CONCLUSION

The UV water disinfection system is proving to be a reliable system which can operate with little or no maintenance. Because it is electrically powered it can be run with solar photovoltaic panels, in most cases without the need of batteries.

This combination makes it suitable for remote locations where accessibility and maintenance are difficult.

REFERENCES

1. "Domestic Water Use in Perth, Western Australia" Water Authority of Western Australia, 1985

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ACKNOWLEDGMENT

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