DRINKING WATER FOR ALL

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Abstract

Impure water is the root cause for many diseases especially in developing countries. Millions of people become sick each year from drinking contaminated water. In many regions of the world, sunshine is abundantly available which can be effectively utilised to provide safe drinking water to the millions of people. A portable, low-cost, and low-maintenance solar disinfection unit to provide potable water has been designed and tested. The solar disinfection system has been tested with bore water, well as well as waste water. In 5 hours, the unit eradicated 3 $\log_{10}$ (99.99%) of bacteria contained in the water samples. The unit will provide about 6 liters of pure drinking water and larger units can be fabricated for providing safe drinking water at community level in developing countries.

Introduction

Every 8 seconds, a child dies from water related disease around the globe. 50% of people in developing countries suffer from one or more water-related diseases. 80% of diseases in the developing countries are caused by contaminated water. Providing safe drinking water to the people has been a major challenge for Governments in developing countries. Conventional technologies used to disinfect water are: ozonation, chlorination and artificial UV radiation. These technologies require sophisticated equipment, are capital intensive and require **skilled operators** (1,17,20). Boiling water requires about 1 kg of wood/liter of water which results in deforestation in developing countries. Also halazone or calcium hypochlorite tablets or solutions (sodium hypochlorite at 1 to 2 drops per liter) are used to disinfect drinking water. These methods are environmentally unsound or hygienically unsafe when performed by a layperson. Misuse of sodium hypochlorite solution poses **a safety hazard** (2,4,11).

Treatment to control waterborne microbial contaminants by exposure to sunlight in clear vessels that allows the combined germicidal effects of both UV radiation and heat has been developed and **put into practice** (5,712,13,14,18,19).The SODIS system(Solar Disinfection of water) developed by scientists at the Swiss Federal Agency for Environmental Science and Technology(EAWAG) recommends placing PET bottles (usually discarded mineral water/beverage bottles) painted black on one side, aerating (oxygenating) the water by vigorous shaking three fourths water filled bottles and then filling them full and placing them in sunlight for 6 hours. In this method, the water is exposed to UV radiation in sunlight, primarily UV-A and it becomes heated; both effects contribute to the inactivation of water borne microbes. The use of PET bottles requires periodic replacement because of scratches and they become deformed if temperature exceeds 65^0C. Also dust accumulates on these bottles in the groves (provided for strength). The PET bottle mineral water manufacturers print on the label,' crush the bottle after use' in India. Unless cleaned thoroughly everyday, PET bottles turn brown over usage rendering lesser transmission of sunlight.

Microorganisms are heat sensitive. Table 1 **lists up the required temperature** to eliminate microorganisms within 1,6 or 60 minutes. It can be seen that it is not required to boil the water in order to kill 99.9% of the microorganisms. Heating up water to 50 - 60^0C for one hour **has the same effect** (2,21).

The most favorable region for solar disinfection lies between latitudes 15^0 N/S and 35 ^{0} N/S. These semi-arid regions are characterised by high solar radiation and limited cloud coverage and rainfall (3000 hours sunshine per year).The second most favorable region lies between the equator and latitude 15 ^{0} N/S, the scattered radiation in this region is quite high (2500 hours sunshine per year).

The need for a low-cost, low maintenance and effective disinfection system for providing safe drinking water is paramount, especially for the developing countries.

Materials And Methods

The innovative solar disinfection system has a wooden frame of length 2 ft,width 1 foot and depth 6 inches with bottom sinusoidal shaped polished stainless steel (curvature slightly larger than standard glass wine bottles, about 5 inches diameter) . On the front is fixed a glass sheet having lifting arrangement with a knob (this glass enclosure will protect the glass bottles from cooling down due to outside wind). There are screws which can be used to keep the contents airtight. On the backside a stand is fixed which will help the unit to be placed according to the latitude of the place for maximum solar insolation.

In this method clear glass bottles (used wine bottles) are utilised instead of PET bottles as the former are easy to clean, lasts longer and are available at a low cost in India. Solar disinfection is more efficient in water containing high levels of oxygen; sunlight produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides) in the water. These reactive forms of oxygen kill the microorganisms. Aeration of water is achieved by shaking the 3/4 water filled bottles for about 20 seconds before they are filled completely.

The unit has an advantage in that the rear reflection stainless steel will pass the light through the bottles a second time, to both increase exposure and eliminate shadowing. This reflection system will increase the light intensity minimum 2 times.

It has been widely experimented and established by earlier researchers that at temperature of 50^0C, pathogenic microbes are inactivated. The temperatures which cause approximately a 1-log decrease in viability with 1 min are 55^0C for protozoan cysts; 60^0C for E.*coli*, enteric bacteria, and rotavirus; and 65^0C **for hepatitis A virus** (3,6,8,9,10,16). **Negar Safapour and Robert H.Metcalf** (15) in their extensive studies reported enhancement of solar water pasteurization with reflectors and the crucial role of temperature above 50^0C in the elimination of pathogens.

Operation

The unit is placed in the south direction (in India) around 10 am with inclination equal to the latitude of the place. The glass bottles are filled with water three fourths and shaken for 20 seconds to generate oxygen and then completely filled. The water filled bottles are fixed with caps and put in the groves of the solar disinfection unit. The glass door is closed and clipped airtight. Water bottles are removed from the unit at 3 pm and taken to a cool place and the disinfected water transferred to a clean vessel, covered for later usage.

Suspended particles in the water reduce the penetration of solar radiation into the water and protect microorganisms from being irradiated. Solar disinfection requires relatively clear water with a turbidity less than 30 NTU.To remove turbidity traditional methods of putting the paste from seed of *strichnos potatorum* (Nirmal seeds) by rubbing the seed on a rough stone with water is used. The method is effective, turbidity settles down in half of an hour and the seed are available in plenty in forests in India besides being inexpensive.

Sample Testing

Water samples from the solar disinfection unit were tested with Most Probable Number (MPN) technique. To estimate the number of aerobic organisms present in water, Pour Plate Technique has been used.

Results

The test results of various water samples disinfected **are presented in** Table 2.
In the samples from Ambattur Bore Water, Ambattur Well Water, Anna Nagar Bore Water and Kavaraipettai Bore Water, since they are highly contaminated, further dilutions were not carried out. The dilution should be done only when the MPN indicates

more than 1100 organisms/100 ml. For these samples only log reductions can be calculated. As regards R.S.M.Nagar Bore Water and Thathai Manji Well Water, the percentage of reduction are 85 and 86.95, which indicates that the water is less contaminated. As MPN index shows less than 3 organisms for 100 ml, after solar disinfection of water, the samples are free from coli forms. The results of Avadi Waste Water and Perambur Waste Water show 3 log reduction (99.8%) and 4 log reduction (99.993%) respectively.

For comparison PET and Glass bottles were placed with black background as well as in the innovative device I developed. The **results were presented in** Table 3.

It can be readily seen that is complete with my device compared to open.

Discussion

Eradication of coli forms from well water, bore water and waste water has been reported from test results. The results confirm that there is 4-log 10 reduction of coli forms in the waste water after solar disinfection. The experiments were conducted at Kavaraipettai,Tamil Nadu,India.Maximum temperature occurs around 1 pm. Though 6 bottles were used in the system(each of 1 liter capacity),larger units with up to 100 bottles can be designed. The unit destroyed 99.99% of bacterial coli forms both in well water and waste water samples in 5 hours.

The innovative solar disinfection system has the advantages like:

1.The unit is portable,

2.It is cost-effective. It can be fabricated in South India for US$ 20.The unit incorporates the principle of reflection to increase solar intensity and has protection from wind which results in temperature rise inside the unit,

3.Larger units can be manufactured,

4. Used glass bottles withstand higher temperatures and are available in plenty each for 2 US cents in South India ,

5. Since all the materials are available locally, the unit can be manufactured locally with local people. Temperatures above 30^0c occur in south India for more than 10 months in a year and as such this innovative solar disinfection unit will be a boon in this region.

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Table1.

Thermo resistance of microorganisms

Microorganisms	*Temperature for 100% Destruction*		
	1 Min.	6 Min.	60 Min
Enteroviruses			62^0c
Rotaviruses			63^0C for 30 Min.
Faecal Colioforms	At 80^0C Complete destruction		
Salmonelae			45^0C
Shigella		61^0C	54^0C
Vibrio Cholera			45^0C
Entamoeba Histolytica Cysts	57^0C	54^0C	50^0C
Giardia Cysts	57^0C	54^0C	50^0C
Hookworm Eggs and Larvae		62^0C	51^0C
Ascaris Eggs	68^0C	62^0C	57^0C
Schostosomas Eggs	60^0C	55^0C	50^0C
Taenia Eggs	65^0C	57^0C	51^0C

Table 2
Test results of samples

AREA OF COLLECTION	NATURE OF WATER	DATE OF COLLEC TION	DATE OF PROCESS ING	AMBIENT TEMPERA TURE (in ^{o}C)	TEMPERA TURE AFTER IRRADIA TION (in ^{o}C)	MPN	TOTAL COLONY COUNT (CFU)	LOG REDUC TION VALUE	% OF REDUC TION
AMBATTUR BORE WATER	RAW	10-02-2005	11-02-2005	32.0	63.0	>1100	55		
	TREATED					<3	04		
AMBATTUR WELL WATER	RAW	10-01-2005	11-01-2005	33.0	61.0	>1100	64		
	TREATED					<3	08		
AMBATTUR BORE WATER	RAW	20-12-2004	22-12-2004	33.5	67.0	43	10000		93.02
	TREATED					<3	200		
ANNA NAGAR BORE WATER	RAW	09-02-2005	10-02-2005	32.5	69.0	>1100	120		
	TREATED					<3	04		
KAVARI PETTAI BORE WATER	RAW	29-12-2004	03-01-2005	30.0	58.5	>1100	150000		
	TREATED					<3	20		
PERAMBUR BORE WATER	RAW	29-12-2004	03-01-2005	30	58.5	1100	12000		99.72
	TREATED					<3	20		
PONNERI BORE WATER	RAW	10-02-2005	11-02-2005	32.0	63.0	43	95		93.02
	TREATED					<3	08		
R.S.M. NAGAR BORE WATER	RAW	08-01-2005	08-01-2005	31.5	66.0	20	1100		85.00
	TREATED					<3	40		
THATHAI MANJI WELL WATER	RAW	29-12-2004	03-01-2005	30.0	58.5	23	5500		86.95
	TREATED					<3	40		
VYASARPADI BORE WATER	RAW	21-12-2004	22-12-2004	30.5	68.0	1100	12000		99.72
	TREATED					<3	250		
AVADI WASTE WATER	RAW	02-03-2005	03-03-2005	35.5	72.0	$15*10^3$	17000		99.8
	TREATED					<3	250	3	
PERAMBUR WASTE WATER	RAW	03-03-2005	04-03-2005	36.0	70.0	$43*10^4$	15500		99.993
	TREATED					<3	175	4	

Table 3

EFFECT OF TEMPERATURE ON DISINFECTION OF WATER

NATURE OF WATER		RAW	GLASS BOTTLE IN THE KIT(I Invented)	PET BOTTLE IN THE KIT(I Invented)	GLASS BOTTLE IN THE OPEN SPACE	PET BOTTLE IN THE OPEN SPACE
DATE OF COLLECTION & PROCESSING	25 –06 -2005					
TEMPERATURE AT 8.30. A.M. (IN ^{o}C)		28.0	28.0	28.0	28.0	28.0
TEMPERATURE AT 2.00. P.M. (IN ^{o}C)	AMBIENT	30.0	30.0	30.0	30.0	30.0
	AFTER IRRADIATION	--------	57.0	52.0	42.0	40.0
DURATION OF EXPOSURE		-------	5.30 HOURS	5.30 HOURS	5.30 HOURS	5.30 HOURS
M.P.N. INDEX VALUE		$93 * 10^{3}$	<3	43	$23 * 10^{3}$	$43 * 10^{3}$
% OF REDUCTION		---------	99.9967	99.9537	75.2688	53.7634
LOG REDUCTION VALUE		---------	3	3	0	0

Innovative Solar Disinfection System