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RESEARCH ARTICLE

FABRICATION OF POTABLE AND ECO-FRIENDLY SOLAR DISINFECTION (SODIS) UNIT AND ITS PERFORMANCE ANALYSIS

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ABSTRACT

Solar disinfection (SODIS) is a technique, which involves utilization of solar energy to make safe drinking water from biologically contaminated water. In the conventional SODIS method, the PET bottles are filled with polluted water and exposed to the sunlight for a certain period depending upon the local weather conditions. However much more effective disinfection system is needed to overcome the problems of inefficient utilization of available solar energy and the health risk posed by treating the water using chemicals during the purification process. Hence, the present work aims in designing a portable solar disinfection unit that can efficiently use solar energy by manually adjusting the unit according to sunlight availability. Along with it, incorporation of the additional eco-friendly unit with water purifying plants *Vetiveria zizanioides* (Vetiver) and *Hemidesmus indicus* (Nannari) is done to achieve high efficiency in producing potable water from biologically contaminated water. The contaminated water samples treated in the solar disinfection unit and eco-friendly water purifying unit are analyzed for the presence of total coliforms and *E-coli* by using the Most probable Number method and P/A analysis, respectively. A reduction in 99.74% of total coliform count and absence of E-coli was observed in the treated water samples. The physicochemical analysis was carried out to ensure the suitability of treated water for consumption and the results revealed a notable reduction in the parameters, and all the parameters came under the permissible range of IS drinking water characteristics. The designed system can be used to disinfect the contaminated water sample most efficiently, thereby making the water suitable for consumption.

Keywords: Solar disinfection, *Vetiveria zizanioides, Hemidesmus indicus,* coliforms, water

1. INTRODUCTION

Water is one of the basic necessity which is required in sufficient quantity and consumable quality for everyone. However, starting of this millennia saw one-sixth of the world's population, around 1.1 billion people without access to proper water supply and many more lacking access to safe consumable water [1]. According to a world water survey, 31% of Indians drew drinking water from unsafe sources, given no other choice, thereby suffering from waterborne diseases. Proper water supply systems are affected due to several factors ranging from lack of maintenance, unreliable public service operations or the water being subjected to secondary contamination during collection, transport and storage [2]. According to a world water survey, lack of potable water poses significant health risks and each year there are over 1.8 million deaths reported due to consumption of contaminated water out of which 90% are children under five years of age. Disease such as diarrhoea, cholera, typhoid fever, jaundice, hepatitis A, amoebic and bacillary dysentery and other diarrhoeal diseases can arise due to no access to good quality drinking water [3,4]. Established water supplies are rapidly at risk of pollution, and population growth creates an increased demand for clean water [5]. Adequate water treatment methods combined with good hygiene promotion and the avoidance of drinking water contamination are a must to prevent any illness and death for any population without access to safe drinking water.

Solar disinfection (SODIS) is a WHO-accepted economical, viable, user-friendly and environmentally safe, household water treatment method that can be used to overcome the problem of unavailability of safe drinking water [6]. The method involves the utilization of solar energy to make biologically contaminated water safe to drink by exposure to sunlight. The SODIS approach has

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shown significant antimicrobial effects in laboratory and experimental field tests and is currently being promoted more in developing countries [7]. During solar exposure, the water is usually heated by solar infrared radiation, depending on the irradiation rate, optimum temperature, and location (wind cooling, heat absorption background). At temperatures above 45-50°C, there is a synergistic effect of thermal inactivation and UV-A radiation which significantly increases the rate of inactivation of solar disinfection. In the case of bacteria, membrane enzymes, e.g. respiratory chain enzymes and F1F0-ATPase, are potentially the first targets of ROS. With constant irradiation, structural proteins and enzymes responsible for various cellular functions (e.g. transcription and translation mechanism, transport systems, amino acid synthesis and degradation, respiration, ATP synthesis, etc.) are also impaired, contributing to cell inactivation and death. [8].

The ultraviolet wavelength of solar radiation and the lower visible range act as the main mechanism behind the pathogen inactivation of sunlight [2]. Among which the prominent inactivation of pathogens is due to the UA-Apart (wavelength 320 - 400 nm), which has a lethal effect on human pathogens present in water. It directly interacts with the DNA, nucleic acids and enzymes of the living cells, changes the molecular structure and leads to cell death. UV radiation also reacts with oxygen dissolved in the water and produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides). These reactive molecules also interfere with cell structures and kill pathogens. Exposure to UV-A radiation induces damage of the cellular membrane and delay microbial growth [9].

The use of plants as water purifiers has been in use since ancient times. *Vetiveria zizanioides* (Vetiver) is a medicinal plant that has been used as a primary purifier of polluted water. The plant is known for its ability to absorb phosphates, nitrates, heavy metals and E-coli bacteria [10]. *Hemidesmus indicus* is a traditional medicinal plant with antibacterial property. An extract from this plant root can inhibit the growth of E-coli, streptococcus, corynebacterium and pneumonia-causing bacteria [11]. SODIS is an efficient method for reducing water pathogens like bacteria, virus, fungi etc. However, it has some limitations, especially regarding the inefficient utilization of locally available solar energy due to inappropriate design of the system and the unavailability of potable solar disinfection unit which can be installed and used for domestic purpose. Moreover, the quality of drinking water produced through solar disinfection is treated using harmful chemicals such as hydrogen peroxide and hence poses a health risk. In this regard incorporation of the eco-friendly unit containing medicinal herbs to treat the output of solar disinfected water helps in overcoming the health risk, which might result from the chemical treatment of water.

Hence the present work, an attempt is planned to design a potable SODIS unit that is suitable for capturing solar radiation available in the district of Coimbatore, thereby achieving disinfection with maximum efficiency. The potable water produced from the SODIS is further purified by incorporation of the additional unit containing eco-friendly natural water purifiers namely the roots of *V. zizanioides* (Vetiver) and *H. indicus* (Nannari) and to achieve high efficiency in producing potable water from biologically contaminated water.

2. MATERIALS AND METHODS

Designing of solar disinfection unit

PET (polyethylene Terephthalate) bottles were used to make a disinfection unit as they are photostable polymers and have a considerable lifetime, excellent strength, stiffness, impact resistance and resistance to high temperature. Since UV radiation is reduced with respect to increasing water depth, a water depth of 10 cm can account for a 50% reduction in UV radiation. Hence 1 litre transparent PET bottles are used. A rectangular box frame was built to aid the working of the proposed solar disinfection unit. Rectangular pipes welded together to form a 42x42 cm box structure, a metallic iron sheet of 2 mm thickness is welded to one of the horizontal frames to act as a platform to hold the PET bottles. Unique bottle holders are provided to hold the bottles in place. The iron platform is covered with aluminium foil to make it a reflective surface to enhance the disinfection process. SODIS unit was made ideal for capturing solar radiation available in the district of Coimbatore. For this, the horizontal frame was made manually adjustable to three different angles, according to the availability of sunlight which varies during different periods of a day. The angles of inclination for the platform was chosen by repeated trials at different angles and by noting the inclinations at which the maximum temperature rise in the samples was observed and chosen as the key angles for manual adjustment using a lever (Figure 1).

Deciding on the angle of inclination was a trial and error process. Starting with the top plate horizontally placed, assuming the most intense sunlight is received at midday and for the next 3 hours until 3 pm, the plate was adjusted at different angles to maximise the amount of the sun falling and reflecting on to the pet bottles. This process was repeated for the next two days starting with the platform at an inclination angle of 45^{o} in the morning and gradually moving to a horizontal at midday. To allow maximum sunlight exposure, the disinfectant unit is lifted and turned to the direction of the sun during the afternoon and late afternoon. The horizontal plate was lifted at 1^{o} -5 ^{o} increments to capture the sunlight every 20 minutes until 3 pm where the angle of the plate was at 45 ^{o} to the horizontal plane. This method was repeated during morning and afternoon time, with 45 ^{o} as the starting point at 9 am and gradually tilted to horizontal or 0 ^{o} at mid-day and 45 ^{o} at the end of the day at 3 pm. Temperature readings are taken before any changes in the angle, and the temperature changes were recorded. The maximum temperature was recorded at 5^{o} angle increments for every 20 minutes for both day time and afternoon sessions and these angular increments are followed throughout the experimental procedure.

The inclination was kept at 45 ^{o} from 10 - 11 am, then the platform was elevated to 25 ^{o} till noon, followed by horizontally placing it at 0 ^{o} from 12 - 2 pm. In the afternoon, the unit was placed facing the changed direction of the sun, and the platform was lowered to an angle of 25 ^{o} from 2-3 pm and to an angle of 45 ^{o} from 3-4 pm.

Sample collection and treatment (Solardisinfection)

The studies were conducted in Coimbatore, which lies between 12°13’ to 12°50’ north latitude and 75°55’ to 75°27’ east longitude. In the present study, contaminated water samples were collected in one-litre bottles from Ukkadam lake (Sample A) (Coimbatore, Tamil Nadu 10.992038, 76.972050) early in the morning in August 2020. The rainwater was allowed to fall for 40 minutes and collected in 1L bottles to treat as control (Sample B).

The collected samples A and B were filled up to two-thirds of the bottles, and they are shaken vigorously for 30 seconds to increase the initial level of dissolved oxygen for the solar-induced oxidative inactivation process. Climatic factors were analysed before exposure to sunlight. Solar disinfection unit holding experimental and control water samples were exposed to natural sunlight for 6 hours during the daytime. The aluminium frame, holding bottles were adjusted at various angles of inclination according to the availability of the sun.

The temperature of the water was recorded using a digital thermometer and noted down periodically. Trials were conducted in August 2020, at ambient temperatures ranging from 30-33 ^{o} C between 11 pm and 4 pm to ensure the highest sunlight intensity.

Treatment of solar disinfected water in Eco- friendly water purifying unit

Roots of medicinal plants, namely *V. zizanioides* and *H. indicus* were purchased, washed and cleaned. Their roots were kept in a water dispenser made of strong plastic of six-litre storage capacity. The top of the dispenser was closed using a plastic lid. 50 gm of each root were kept at the bottom of the container. Water samples treated in the solar disinfection unit was transferred separately into the container, and each sample was kept for 6 hours. The water outlet from the container is fixed 5 cm above the bottom level (Figure 2). Water samples were drained from the container for consumption after treatment with the medicinal herbs.

Figure 1. Solar disinfection unit at various inclinations

Figure 2. Ecofriendly water purification unit

Microbial analysis and Sample testing

Laboratory microbial analysis is carried out in the water samples treated in the solar disinfection unit and purified using the eco-friendly purification unit to find the rate of microbial disintegration. Samples were analysed for the presence of total coliforms and *E-coli* by using the Most probable Number method and P/A analysis respectively by using the method prescribed by APHA 2012 [12]. It is the most commonly applied test to ensure whether the water is safe in terms of bacterial presence. For untreated water double strength medium is dispensed to 10 tubes (10 mL) and single strength medium in 5 tubes and Durham tube is added in an inverted position and for treated water, the double strength medium is dispensed into 5 tubes, and 50 mL single strength medium in 1 bottle and Durham tube is added in an inverted position. It is followed by sterilization by autoclaving at 15 Ibs pressure (121°C) for 15 minutes. To find out the MPN of coliforms, for untreated polluted water,5 tubes of double strength and 10 tubes of single strength for each water sample is taken.10 mL,1 ML and 0.1 mL water is added using the sterile pipette to every 5 tubes containing 10 ML double strength and single strength mediums respectively. For treated unpolluted water 1 tube of single strength (50 ML) and 5 tubes for double strength (10 mL) for each water, the sample is taken, 50 mL of water is added to the tubes containing 50 mL single strength medium and 10 mL of water is added to 5 tubes containing 10 mL single strength medium. All the tubes were incubated at 37° C for 24 hrs. The number of tubes giving a positive reaction is compared to the standard table, and the number of bacteria present is recorded.

For E-coli P/A analysis, 100 mL of the water sample is filtered through a 47-mm, 0.45-µm pore size cellulose ester membrane filter that retains the bacteria present in the sample. The filter is mounted on a 5-mL MI agar plate or an absorbent pad saturated with 2-3 mL MI broth, and the plate is incubated for up to 24 hours at 35 °C. The bacterial colonies that emerge on the plate are examined for the appearance of blue colour from IBDG 's breakdown by E-coli. Enzyme $-glucuronidase and fluorescence under long-wave ultraviolet light (366 nm) from the breakdown of MUGal by TC enzyme $-galactosidase [13]. The water is analysed for other parameters. It is very essential that water must be tested for other physiochemical parameters before it is used for drinking purpose. Following different physicochemical parameters are tested for monitoring water quality. All the parameters were analysed by the standard method prescribed by APHA 2012 [12].

2. 5. Analysis of Physicochemical Parameters: Temperature, pH and Turbidity:

The surface water temperatures were measured periodically using a digital thermometer, pH is indicated by using a digital pH meter (ELICO, L110), the odour is measured by threshold odour test, TDS by TDS meter and turbidity was measured by using turbidity meter.

Total Hardness and Alkalinity:

The total hardness of the water samples is estimated by titrating the samples against EDTA using Eriochrome Black-T(EBT) indicator. Alkalinity is measured by using sulphuric acid with a digital titrator. Sulfuric acid is added to the water sample in calculated concentrations until the three main forms of alkalinity (bicarbonate, carbonate and hydroxide) are converted into carbonic acid. At pH 10, the hydroxide (if present) reacts to form water.

Calcium and Magnesium:

It is measured by complex metric titration with standard EDTA solution using patterns and reader's indicators under pH conditions of more than 12.0. These conditions are achieved by the addition of a fixed amount of 4N Sodium Hydroxide. The concentration of calcium was obtained by titration of EDTA solution against the known volume of the sample. It is also calculated by complexometric titration with EDTA standard solution using Eriochrome Black T as an indicator under pH 10.0 buffer conditions. The buffer solution is composed of Ammonium Chloride and

Ammonium Hydroxide. The solution withstands pH differences during titration.

Sulphate and Chloride:

Sulphate is analysed by the nephelometric method. This approach is based on the fact that the sulphate ion can be precipitated by barium chloride in an acetic acid solution. Measurement of the light scattering of the resulting suspension is done using a nephelometer, and the sulphate concentration is measured by comparing it with the standard curve. In this procedure, chloride ions are measured by titrating directly with silver ions (silver nitrate) using fluorescein as an indicator. Fluorescein is a weak acid that is partly dissociated in water to form a fluorescein anion. The endpoint was determined by the colour change from yellow-green to red or pink.

Chlorine and Iron

It was measure by using the DPD titration method. In this method, DPD is oxidised to the magenta-colour species by chlorine (or iodine in the case of chloramines). The red colour is then titrated with a ferrous reducing agent to the colourless endpoint. Iron content is measured by the phenanthroline spectrometric method. In this procedure, Iron + II is reacted with o-phenanthrol to create a coloured complexion. The intensity of the coloured solution is measured using the spectrophotometer. The calibration curve (absorbance vs concentration) is developed for iron + II, and the concentration of the unknown iron sample is determined.

3. RESULTS

Microbial analysis

Total coliform bacteria are the indicator organisms that their presence indicate other disease-causing organisms present in water, and it is useful for analysing the pollution status of the ecosystem. The result of the microbial analysis of the samples after disinfection using the solar disinfection unit and further purification in the eco-friendly purification unit resulted in a drastic disintegration in the microbial population of total coliforms and the absence of E. coli.

The amount of total coliforms was present in the contaminated water before treatment was found to be 2400.00 MPN /100mL in sample A (Table 1). The data showed which showed significant disintegration after treatment in the solar disinfection unit which was found to be 750 MPN /100mL and again on carrying out further purification using medicinal herbs, the count was found to be 9.00 MPN/100mL. In control water sample B, the total coliforms count before and after solar disinfection was found to be 120.00 MPN /100mL and 47.00 MPN /100mL, and after treatment in the purification unit, the count was found to be 3. 00 MPN /100mL. In both the samples MPN of coliform bacteria came under IS drinking water characteristic count of <10 nos.in 100ml. P/A analysis of E-coli revealed that E-coli present in raw water sample A was completely absent in treated water samples, whereas in sample B the E-coli was absent in raw water.

Analysis of physicochemical parameters

Table 2 shows the data for the physicochemical characteristics of experimental and control water samples.

Temperature

The temperature difference before and after the solar disinfection of sample A showed a gradual rise from the initial value of 27.3°C at an inclination of 25◦C (10 am-11 am) to 36.8 °C at 45^0 inclination (11 am-12 pm) and attained a maximum rise to 52.2°C when kept horizontally during the period of 12 pm-2 pm and during afternoon showed a gradual decrease to 49.5°C (2 pm-3 pm) and further to 47.3°C (3 pm-4 pm) when kept at an inclination of 45°C and 25°C respectively, and that of sample B showed the similar pattern of temperature variation with a maximum value at 49.2°C (Table 3).

pH

The pH of samples was within the permissible range of IS drinking water characteristic. the pH of both water samples did not show any significant change after solar disinfection, and it increased slightly after treating in the eco-friendly purifying unit from 6.63 to 7.72 for sample A and from 6.80 to 7.20 in sample B.

Turbidity and Total Dissolved Solids (TDS)

The turbidity and TDS were extensively higher than the characteristic value in raw water sample A, and it decreased somewhat after solar disinfection and drastically decreased after treating in the eco-friendly unit. The TDS was decreased from 1190.0 mg/l to 830.0 mg/l after solar disinfection and further decreased to 450.0 mg/l after purification. The initial turbidity value of sample A (17.00 NTU) which was higher than the permissible range of 15.00

NTU decreased to 14.00 NTU after solar disinfection, and it showed a huge decrease to a value of 2.00 NTU after purification. In sample B, the water was relatively clear before disinfection, and the values decreased slightly after purification.

Table 1. The data shows the microbial analysis of water sample

S. No.	Parameters (units)	Sample A (Experimental)			Sample B (Control)		
		Raw Water Sample	Sodis Treated	Eco-friendly purified	Raw Water	SODIS Treated	Eco-friendly purified
1	MPN of Coliform Bacteria for 100 ml	2400 MPN/100 ml	750 MPN/100 ml	9.00 MPN/100ml	120 MPN/100 ml	47.00 MPN/100 ml	3.00 MPN/100 ml
2	E.coli P/A	Present	Present	Absent	Absent	Absent	Absent

Table 2. The data shows the Physiochemical parameters of disinfected water samples

Sl. No.	Physico-chemical Parameters (units)	Sample A (Experimental)			Sample B (control)		
		Raw Water	SODIS Treated	Eco-friendly treated	Raw Water	SODIS Treated	Ecofriendly purified
1	pH	6.60	6.63	7.72	6.80	6.80	7.20
2	Odour	Mild odour	No odour	NO Odour	No Odour	No Odour	No Odour
3	TDS (mg/l)	1190.0	830.0	450.0	28	27.6	12.3
4	Turbidity (NTU)	17.00	14.00	2.00	3.4	3.14	0.27
5	T. Alkalinity (mg/l)	340.00	338.00	72.00	31.00	30.4	6.5
6	Total Hardness (mg/l)	380.00	365.00	220.00	73.00	71.6	32.20
7	Calcium (mg/l)	68.00	67.00	48.00	9.40	9.38	7.2
8	Magnesium (mg/l)	50.00	50.00	24.00	1.2	1.18	0.7
9	Chloride (mg/l)	243.0	249.00	237.7	5.47	5.45	3.78
10	Sulphate (mg/l)	241.00	240.00	160.0	3.40	3.35	1.27
11	Chlorine (mg/l)	Nil	Nil	Nil	Nil	Nil	Nil
12	Iron (mg/l)	1.30	1.29	0.28	0.83	0.82	3.1

Table 3. Temperature of water samples during exposure in solar disinfection unit.

Water sample	Temperature (period and angle of inclinations)				
	10 am-11 am (25^{o})	**11 am-12 pm (45^{o})**	**12 pm-2 pm (0^{o})**	**2 pm-3 pm (45^{o})**	**3 pm-4 pm (25^{o})**
Sample A	27.3	36.8	52.2	49.5	47.3
Sample B	23.4	33.5	49.2	48.0	45.9

Total alkalinity and hardness

Total alkalinity and hardness of water sample A were higher than the permissible limit before treatment. It decreased slightly after solar disinfection from 340.00 to 338.00 mg/l and changed drastically to 72.00 mg/l and reached within the permissible limit after treating in purifying unit.

Calcium, magnesium, chloride and chlorine

In the sample, A magnesium, content didn't improve after SODIS treatment, but it decreased from 50 mg/l to 24 mg/l after purification. Chlorine was absent in both raw water samples A and B. Total calcium and chloride content was within the permissible range in raw sample A, and it showed a decrease in a small amount after SODIS treatment and in a large amount after purification.

Sulphate and Iron

Sulphate content was higher than the water characteristic, and it did not show any change after SODIS but changed from 240 mg/l to 160 mg/l after purification in the experimental sample. Total iron content was far higher than the permissible limit in raw water sample A, but it decreased drastically from 1.30 to 0.28 mg/l after purification.

In control water sample B, all parameters were within the permissible limit in the raw sample itself, and it did not show any notable change after SODIS but decreased drastically after treatment in eco-friendly water purifying unit.

4. DISCUSSION

The results of the performance analysis in the present study showed that the Eco-Friendly Solar Disinfection Unit prepared could efficiently purify the contaminated water, making them suitable for consumption. The solar disinfection unit was designed in such a way that it ensured the maximum availability of sunlight. The reflective surface provided using the aluminium sheet as the base boosted the amount of sunlight absorbed by the water. Aluminium is the only material that has a high reflectivity for ultraviolet rays in the wavelength spectrum ranging from 250 nm to 400 nm. An aluminium foil that is lightweight and has strong workability is ideal as an ultraviolet reflective material. Moreover, these are mechanically robust, water-proof, long-lasting and affordable [14]. Previously large number of works has been carried out using aluminium foil in solar equipment such as solar water heater [15], solar cooker [16], photovoltaic solar panel [17] etc.

In the present work, the design of a potable SODIS unit was made suitable for capturing solar radiation available in the district of Coimbatore. The placement and orientation of the solar disinfection unit is an important factor that the angle or tilt of the unit should able to harness the maximum intensity of sunlight. In this work, the angles at which maximum sunlight intensity was chosen by trial and error procedure followed by the manual adjustment of the reflective platform to different angles of inclination according to the sunlight availability during different periods of the day ensuring the maximum availability of sunlight. The incorporation of the additional unit containing eco-friendly natural water purifiers namely the roots of *V. zizanioides* and *H. indicus* to treat the output of disinfected water helped in achieving high efficiency in producing high purity potable water from biologically contaminated water.

The results of the microbial analysis revealed the significant microbial disintegration of E-coli and total coliforms. In sample A, before the treatment, the total coliforms count was found to be

2400 MPN/100 mL, and after the treatment, a drastic decrease of the coliform count was observed and was found to be 9.00 MPN/100mL. This equated to a reduction of 99.74% of the total coliform count, which is close to the value of 97.5 % of total coliform reduction in a control water sample, thereby indicating that the solar disinfection unit was efficient in treating the contaminated water and making it suitable for consumption. The total coliforms after solar disinfection were reduced to 750 MPN/100mL, and this significant reduction can be attributed to the effect of sunlight on the coliforms. Complete eradication of E-coli from raw water samples was observed after purification of solar disinfected water using herbs. It is available from the previous literature that sunlight can act as an effective agent for the removal of coliforms and E-coli from water samples [18, 19]. On further purification, by medicinal herbs, the total coliforms count reached within the permissible range. Studies carried out by Gerrad et al., [10] and Luqman et al., [20] proved that the roots of *V. zizanioides* has the ability to absorb E-coli bacteria and the work is done by Ganesan et al., [11] and Mamatha et al., [21] showed the ability of roots of *H. indicus* to inhibit the growth of E-coli. Investigation of the effect of vetiver grass in the purification of wastewater carried out by Mathew and the team revealed that the root has the potential to reduce the total coliform count in water up to 85% [22].

In a study conducted by Das et al., [23], the extracts from the roots of *H. indicus* inhibited the E-coli growth, and it was found that the presence of bioactive compounds such as steroids, tannins, saponins, glycosides, flavonoids, and polyphenols might contribute to this antibacterial activity. Work conducted to investigate the effect of roots extracts of *V. zizanioides* implied that the presence of tannins can be the active compound responsible for antibacterial activity against E-coli bacteria [24].

The reduction in coliforms and absence of the E-coli in experimental samples after disinfection and purification can be attributed to the following factors: i) Antibacterial effect posed by the roots of *V. zizanioides* and *H. indicus* inhibited the growth of E-coli. ii) Use of reflective surface in the disinfection unit aided the increased absorption of sunlight. iii) The manual adjustment of the unit according to the availability of sunlight during different periods in daytime resulted in the maximum capturing of available sunlight, and the effect of solar radiation resulted in the ROS formation and disruption of cellular activity and bacterial death.

The physicochemical parameters are crucial for estimating the water quality, as they provide information on the suitability of water for consumption. The temperature rise was maximum found to be 52.2, whereas there was no significant change in pH. After treatment, all the physicochemical and microbial testing parameters were within the permissible IS drinking water characteristics. The physiochemical parameters of both experimental and control water samples did not have any notable change after solar disinfection as SODIS cannot change the physical and chemical quality of water. Still, a significant reduction was observed in these parameters after treating in eco-friendly unit with medicinal herbs, and every parameter came under the IS drinking water characteristics.

Roots of *V. zizanioides* (Vetiver) contributed to the significant decrease in physiochemical characteristics of water samples. It can act as a water purifier and can reduce the turbidity, TDS, alkalinity, hardness of water and aid in the increase of PH of Water. In a study carried out to investigate the effect of vetiver grass in the purification of wastewater by Samuel and the team, it was found that the root can reduce the turbidity and TDS of water samples significantly [25]. The potential of vetiver grass in wastewater treatment was analysed by Maharajan and his team [26] and the results of the study showed that treating of waste water by vetiver grass can reduce the overall concentration of chloride nitrate total hardness and alkalinity by 42.90%, 93.93%, 46.4% and 22.2% respectively. It can also lower the parameters such as chloride, sulphate, calcium; magnesium and iron [26-28]. This could be the reason for the drastic change in the parameters of water after treatment. The discrepancy between the final values of physicochemical parameters of experimental and control samples was not very important for the purposes of the present study as tests were carried out to assess the efficacy of disinfection in terms of microbial percentage removal and not certain physical and chemical parameters.

5. CONCLUSION

An efficient, low cost, Eco-Friendly Solar Disinfection Unit for potable water was designed that can purify the contaminated water, making them suitable for consumption. The system designed is environmentally sustainable since it doesn't make use of electrical energy like commercial water purifiers and used natural plants as purifiers without the use of chemicals. The designed system was able to overcome the major drawbacks of the conventional disinfection unit such as the unavailability of portable solar disinfection unit which can be installed and used for domestic purpose and the inefficient utilization of locally available solar energy due to inappropriate design of the system. The portable unit, which is specially designed for the Coimbatore district, allows maximum capturing of sunlight according to the incidence of radiations and ensured the maximum temperature rise in water samples thereby enhanced the disinfection of contaminated water. A notable reduction was observed in microbial content in the treated water sample. The disinfected water, which is further, purified by incorporating additional unit containing eco-friendly natural water purifiers, namely the roots of *V. zizanioides* and *H. indicus*. In conventional treatments, the output of solar disinfected water is treated using harmful chemicals such as hydrogen peroxide that poses a health risk. This concern was solved by using the roots of medicinal herbs. The roots selectively absorbed and inhabited the coliforms and E-coli and further enhanced water purification, making the contaminated water free from harmful microbes. The physicochemical parameters of water were significantly reduced after treating in the water-purifying unit, and all parameters came under the permissible range, thereby making the water suitable for consumption.

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