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Well Water Disinfection in Wukari Using Solar Energy

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Abstract:
The disinfection of water using solar energy (SODIS) is a simple and inexpensive purification technique. The system has feast through the emerging world and is in everyday usage across over 50 nations both in Asia, Latin America, and Africa. Over an estimated 5 million people sterilise their intake water using solar disinfection (SODIS) method. Well water disinfection using solar energy (radiation) in Wukari town, the technique consists of placing water into transparent plastic or glass containers (normally 1 L PET beverage bottles) which are then exposed to the sun. Exposure times vary from 10am to 6pm depending on the intensity of sunlight and sensitivity of the pathogens. Its bactericidal outcome is built on the mutual effect of warm air heating of solar sunlit and UV radiation. It has been repeatedly shown to be effective for eliminating microbial pathogens and reduce diarrheal morbidity including cholera. Beginning from 1980 to date, report has shown that, much research has been conducted to explore the mechanisms of solar radiation induced cell death in water and conceivable improvement techniques of making it faster and safer. This report was on practical attempts to revise all relevant knowledge about solar disinfection from microbiological issues, laboratory research, solar testing and including real application studies, limitations, as well as examining the factors influencing adoption of the technique and health impact.

Keyword: Disinfection, Escherichia coli, Solar radiation, Staphylococcus aureus, Ultraviolet ray

INTRODUCTION

In our world, water is very important in carryout most of our human activities, "Water purification is the process of removing contaminants" from a water source so to be used for drinking, washing and industrial purposes. Purification occurs to limit the levels of certain components of the water so to reduce the potential associated health risks. The world health organization has identified 752 substances that may be present in well water" [1], and it is many of these elements that purification aims to remove. From "minerals, fungi to parasites, viruses and organic matter" the levels of these elements need to be reduced to minimal quantities for water to be classified drinkable. Water purification techniques have evolved with advancing technology over the past decades, from "simple systems based on the imitation and adaptation of naturally occurring processes" such as sand filters, to the complex methods.

The technique of solar water disinfection (SODIS) is thought to date back to 4000 BC, SODIS was first studied in-depth in 1979 by Aftime Acra, a researcher and Professor in the Department of Environmental science at American university in Beirut. He, with his assistant, Yester Karahagopain, developed a disinfection method that was easy to use and relatively inexpensive. Acra claimed that pathogenic microorganisms present in water could be very easily destroyed with solar radiation, especially ultraviolet radiation [2]. In 1991, the Swiss Federal Institute of Environmental Science and technology and various departments of water and sanitation in

developing countries confirmed that SODIS helps inactivate bacteria, parasites, and viruses in water. SODIS has been used extensively in developing countries since that time.

The World Health Organization (WHO) approximations had it that, about 780 million individuals globally don't have access to clean water [3]. Having access to a clean water supply is essentially, not only to prevent fatal dehydration but also for sanitation purposes, as more than 3.4 million people die each year from water sanitation and hygiene related causes [1]. The WHO also states that there is a clear connection between improved water treatment and economic growth, followed by an overall development of the area. According to their report, [4], making water a part of economic development, poor countries with improved access to clean water and sanitation services had an annual average economic growth of 3.7%. This is far higher than the average annual growth of 0.1% for similarly poor countries without the improved water quality. This is due partly to the fact that improved water treatment means less incidents of water related illnesses, which in turn strengthens the country's work force and boosts productivity, while decreasing the health care burden. It also has a positive effect on education since fewer children miss school because of regular illness. This improves the country's overall education which increases the skilled labour force and further enhances the economic growth and development of the country. The WHO report 1 also states that "Actins that target poor people have the largest marginal effect." meaning there is an enormous importance in improving water treatment in any developing country. Especially in rural areas (which tend to be the poorest). A lot of progress has been made in recent years in improving the water standard in highly populated areas where there is access to a more developed infrastructure, with electrical grids and a larger demand for clean water. Less developed are water sanitation techniques for areas with lower population densities, where any method of water purification needs to be independent of electricity since there is most likely no access to electrical grids. To provide cleaner domestic water to rural populations in third world countries new cheap and cost-effective methods for water sanitation is of vital importance. When implementing any kind of water sanitation in an area, consideration must be taken regarding potential lack of special skills and knowledge about water sanitation, since these areas largely coincide with areas of illiteracy and very limited education. Consideration also must be made regarding the previous stated lack of electricity. This means that any purification process chosen needs to be easy to maintain, work independently from electrical sources, and be housed in a facility with both low investment and maintenance costs, to make it affordable for more people. The economic aspect is very important, not only for the resident population but also to get people elsewhere to see it as a viable method of water sanitation and motivate different types of benefactors such as relief organizations to help finance the construction of water purification facilities in rural areas.

Significance of the Study

The project was targeted at sensitization and orientation of the people of Wukari local Government Area and the public, especially the students and researchers within and without Federal University Wukari, to understand the importance of well water disinfection using solar energy and to prevent the people of Wukari from drinking contaminated water.

Solar Water Disinfection Concepts

According to Wegelin [5], solar water disinfection is a treatment process in which water is exposed to sunlight over time. Solar water disinfection is an environmentally friendly and low-cost method to disinfect water. The solar water disinfection on which this work focuses is known as SODIS.SODIS involves placing water to be treated in a clear, plastic bottle and exposing it to the

sunlight for a sufficient time to inactivate pathogenic microbes [6]. According to Parsons [7], solar water disinfection occurs via three mechanisms which, individually or collectively, may kill or otherwise inactivate pathogenic Microorganisms:

1. DNA alteration by ultraviolet light
2. Production of reactive photo-oxidation species
3. Thermal inactivation

The process of solar water disinfection is generally effective between 35°N and 35°S. For areas outside of this region, SODIS does not tend to be very effective because of limited solar radiation and a colder climate [7]. Solar water disinfection is widely used in about 31 countries by more than two million people for water disinfection [8].The World Health Organization 2002 [9] states that SODIS in general is a cost effective and environmental sustainable process which employs solar radiation in the spectrum of UV-A light (wavelength 320-400nm)and heat (which causes an increase in water temperature) to destroy the pathogenic microorganisms present in biologically contaminated water contained in the bottle. According to Kenya Water for Health Organization 2009, [10], guidelines for drinking water, SODIS is a viable alternative method for disinfection of water in small quantities at a household level in which only solar energy is involved. The SODIS process is quite simple. Generally, clean 1L polyethylene terephalate (PET) bottles are used. Low-turbidity water (<30NTU) is poured to fill the plastic bottles, and the bottles are then shaken to increase the dissolved oxygen content. The bottles are then exposed to sunlight for an extended period. In full sunlight, this period is 6-8 hours. If the temperature of water inside the bottle reaches 45-50 degrees Celsius, then disinfection is about three times more effective. If the weather is cloudy, then the bottles are exposed to sunlight for 48 hr or more to achieve below-detectable levels of bacteria. If the temperature of the water inside a 2L PET bottle in less than 20°C, then UV radiation is the only responsible agent for water disinfection [5], and the process of disinfection may take considerably longer. According to Shanahan, [11], the solar water disinfection threshold for microbial disinfection of drinking water generally involves solar exposure to 3-5 hours of solar radiation above 500W/m^2. Strong synergistic occurs if the temperature of the water is above45°C. The increase in temperature of water exposed to sunlight is caused due to absorption of red and infrared light creating heat. If the temperature in the water rises to 55°C, then the thermal process by itself is responsible for the inactivation process.

TURBIDITY

The efficiency of SODIS is very much inversely dependent on the turbidity of water. Turbidity is a measure of the cloudiness of water. Cloudiness in water is generally due to presence of clay, silt, finely divided organic and inorganic matter, and it is measured as turbidity [12]. According to SANDEC report [13], turbidity of the water to be treated by solar water disinfection should be less than 30 NTU, where NTU is the acronym for nephelometric turbidity units, a measure inversely related to optical clarity. Solid particles in water that is to be treated via SODIS tend to decrease optical clarity and tend to block the passage of ultraviolet radiation through water, thereby decreasing the efficiency of the SODIS process. If the turbidity of water to be treated via SODIS is more than 30NTU, the water should be pre-treated before it is use, using sedimentation or straining [12].

ULTRAVIOLET RADIATION

In SODIS, radiation in both the infrared and ultraviolet ranges is used to disinfect water. As shown in Figure 1. both infrared and UV radiation lie in portions of the electromagnetic spectrum of light.

Heat is produced due to absorption of light in the infrared spectrum, and ultraviolet radiation tends to inactivate pathogenic microorganisms.

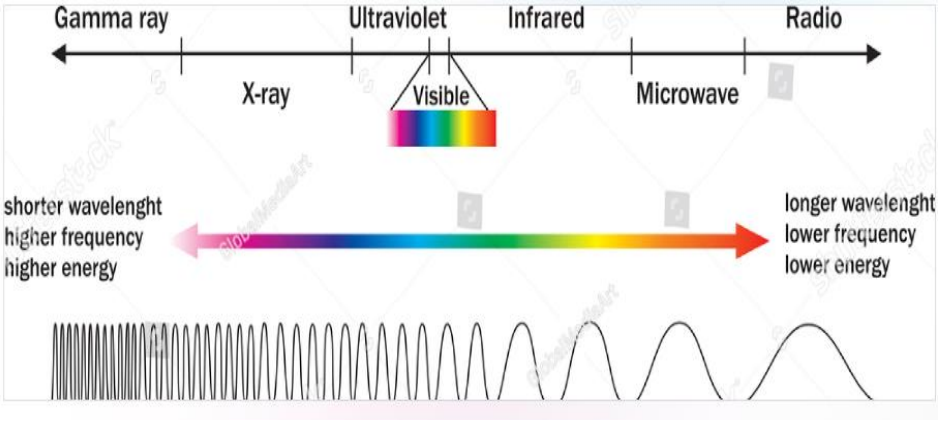

Figure 1. the infrared and UV portions of the electromagnetic spectrum. (Adopted: https://www.shutterstock.com/image-vector/visible-light-diagram-color-electromagnetic-spectrum-)

Table 1. shows the optical radiation spectrum.

Region	Wavelength range
UV	100 – 400 nm
UVC	100 – 280 nm
UVB	280 – 315 nm
UVA	315 – 400 nm
Visible	400 – 780 nm
Infrared (IR)	780nm – 1 mm
IRA	780 nm – 1.4 μm
IRB	1.4 μm – 3.0 μm
IRC	3.0 μm - 1 mm

Ultraviolet radiation is divided in to three different types as shown in table 2.1 of radiation. depending on the wavelength. There are three basic types.

1. Ultraviolet A-Rays
2. Ultraviolet B-Rays
3. Ultraviolet C-Rays.

Type 1 UV-A

Wavelength:320-400nm.This type of radiation is not absorbed by the earth's ozone layer. UV-A radiation damages DNA of living cells which helps in inactivating the cells. Highly reactive oxygen species are produced due to absorption of UV-A through photo sensitizers that cause base changes and strand damage of the microorganisms [14].

Type 2 UV-B

Wavelength:290-320nm.This type of radiation is not completely absorbed by the ozone layer. Only 1% of this radiation reaches earth surface.

Type 3 UV-C

Wavelength:100-290.This type of radiation is totally absorbed by the atmosphere layer.

Effect of Ultraviolet (UV) To Microorganism Cells

The basic mechanism of microbial UV inactivation is the dualism of photo thermal and photochemical effects. The photo thermal impact is because of surface heating by absorbed UV energy. Evidence was if UV radiation causes cellular rupture by overheating if fluencies exceed 0.5 J/cm2; however, other studies suspected photo thermal effects to be of minor importance as inactivation of microbial cells with UV light was also successful at low surface temperature. Explicit photochemical impacts originate from the captivation of UV light by pyrimidine and purine bases in nucleic acids and nucleoproteins. Light sources enable direct DNA damage by stimulating single strand breaks and formation of covalently linked thymine dimers, which inhibit correct transcription and replication. However, pulsated light is suspected to cause extend membrane damage and elution of cellular contents, presumably because of its higher peak power. Indirect effects arise from UV induced photochemical generation of peroxyl or hydroperoxyl radicals that are highly reactive oxidizers and attack ligand membranes, proteins, enzymes, and DNA. This effect can be enhanced by additives that liberate reactive species upon UV radiation; in that case, the object to be decontaminated is coated with a solution containing the photosensitizer (e.g., H_2O_2). As regards susceptibility toward UV, gram-negative bacteria are most sensitive, followed by gram-positive, fungi, and bacterial spores. Pigmentation is also probably protective because of partial UV absorption.

Infrared (IR):

It is a type of electromagnetic radiation with longer wavelengths than those of visible light, and is therefore generally invisible to the human eye, it is including wavelengths between 780 nm and 1000 μm. IR is divided into different bands: Near-Infrared (NIR,0.78-3.0 μm), Mid-Infrared (MIR,3.0-50.0μm) and Far-Infrared (FIR,50.0-1000.0 μm) as defined in standard ISO 20473:2007 Optics and photonics-Spectral bands.

Solar Radiation and Cellular Damage:

The solar irradiance incident on the outer Earth atmosphere is approximately 1360 W m-2-this value varies with position within the elliptical sidereal orbit of the Earth as it orbits the Sun. Water vapor,CO2,ozone and oxygen, in addition to pollutants in the atmosphere, scatter and absorb various portions of this such that for a typical cloudless atmosphere in summer at the equator, the received irradiance on a horizontal surface at ground level on the equator is reduced to roughly 1120 W m-2.Thus we have 1.12 kJ m-2 of optical energy available in each second to inactivate whatever microbial pathogens are present in water exposed to sun-light.

Solar Reactors for Water Disinfection:

While plastic bottles are cost-effective reactors, one of the main drawbacks is the limit they place on the unit volume treated water, usually less than 2 L per batch. If greater batch reactors or containers are required, then the ability of the reactor wall to transmit sunlight is one of the most important criteria. In this regard, non-coloured glass is preferred. Extensive work by Acra et al. showed that ordinary glass bottles and glass jars could transmit up to 90% of solar radiation particularly in wavelengths in the UV-A region. Borosilicate glass tubes could be a good solution for flow solar reactors since they transmit up to 90% of the available UV-A as well as 45% in the more germicidal UV-B range, making glass a more suitable option [15].

Aluminium Foil:

The SODIS bottles are usually only illuminated on the upper side of the reactor that faces the sun. There have been several attempts to concentrate solar radiation using Aluminium foil with the

aim of increasing the radiation inside the bottles. Aluminium foil conferred to the back of the bottles increased disinfection rate constants by a factor of 2. Rijal and Fujioka used also solar reflectors and observed improved efficiencies which they attributed solely to the increase in water temperature of the system. Reflective solar boxes can reduce disinfection time to 3-4 hours.

Trapping Solar Energy:

The methods from Dhaka University are constructed in a way that captures solar insulation. The solar insulations have the form of electromagnetic waves with a large range of wavelength that includes all spectrums from ultraviolet, visible, short infrared and long infrared radiation [16]. When they reach earth some of the radiations filter though the atmospheric layer of gases. Some of the radiation gets absorbed on earth and their energy contributes to heat up the temperature that makes this earth habitable for animals and plants to live [17]. These warm objects then radiate long infrared radiation, some of which passes through the atmospheric gas layers back to space again, otherwise the temperature would be unbearable to live on earth.

Ability to Heat Up a Thick Water Layer:

The water can utilize both trapped solar energy and UV-light simultaneously, which is a big advantage. This deign usually have a surface glass which trap the radiation (heat) inside the constructed solar disinfectant box, this is mainly to block heat inside the disinfectant due short solar wave, aluminium foil This is mainly to reflect the solar rays to fall on the water inside the constructed disinfectant. Under the constructed disinfectant box is painted black colour which absorbs heat which help rise the water temperature. The black surface absorbs solar energy, heats up, and warms the lowest layer of water through conduction figure (2.2).

The whole water layer is then heated through convection. A transparent aluminium foil sheets are spread on top leaving air gaps in-between. Separating items, such as hay straws, could be used to prevent the plastic sheets from touching each other. The air gaps provide insulation to prevent heat loss towards the top. The transparent covers and water allow visible and short infrared solar radiation to reach the black surface below. The long infrared solar radiation is emitted by the heated water and gets trapped by the transparent aluminium foil sheet above, [18]. It needs to be mentioned that the aluminium foil can get affected after some time of use, therefore be aware to exchange then while turning gloomy so that the infrared radiation can reach the water. In this device UV-light also passes on to the water layer.

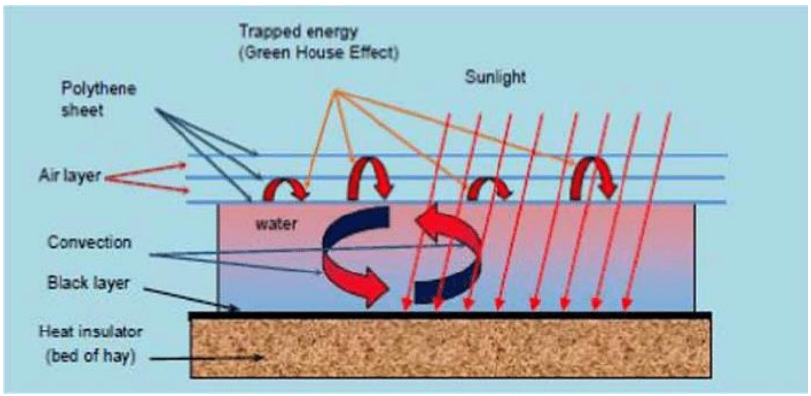

Figure 2; Schematic picture of solar water pasteurization and trapping of solar radiation. (Adopted; https://www.researchgate.net/figure/Schematic-of-solar-water-pasteurization-device-mechanism)

MATERIALS AND METHODS

Materials

The materials used for the analysis is the work, they include.

1. l litre of pet (polyethylene terephalate) bottles use for collection of water samples
2. Construction of crate box
3. Aluminium foils use for the collection of sun radiation
4. Wire loop use for picking organism or growth
5. Slide for creating smear
6. Plate or Patrice dish use for culturing
7. Gas cylinder for heat fixing
8. MacConkey 4.8g and Nutrient Agar
9. Water (100g)
10. Conical flask
11. Safranin, crystal violet gram's iodine
12. Incubator use for temperature
13. Microscopes
14. Autoclaves, Hot plates,
15. Thermometer
16. Colony counter
17. Scale balance
18. Hot plates,
19. Solar power meter (pyranometer)

Study Area and Sampling:

The study was conducted in Wukari, a town located in the Southern part of Taraba State, with latitude 7.85°N, longitude 9.78°E with altitude 152, Nigeria. It is one of the largest local Government areas of the State with three wards. Well water constitutes the major source of drinking, bathing, and other domestic purposes in this area. Most of the wells under study were privately owned and are usually open to public. Drawing of water from these wells is done using 5-10 litre containers tied to a long rope. The wells are not less than 4 years old. Samples were collected from the three areas (federal University Wukari campus area, wapanghaku, Takum junction area and best centre) and three stream samples (Mission quarters 1, Mission quarters 2, and Banana Island) of the local Government area between April and May 2023. Water samples from four wells and three samples of water from the streams mentioned above were randomly collected for analysis.

Sample Preparation:

Stage 1: Collection of Water Samples (Well and Stream):

Water samples were collected in sterile bottles from the various wells as shown in plate 3.1 following a method described by Ngwa and Chrysanthus (2013) with slight modification. The sterile bottles were tied with a strong string to a piece of metal of about 400 g. The bottles caps were aseptically removed, and the weighted bottle lowered into the well to a depth of about 1.5 meters. The bottle was brought up to a surface and covered with a screw cap ensuring no air bubbles inside and was transported to the central laboratory, Federal University Wukari for further analysis.

Figure 3. Images from the Local wells (site pictures)

Stage 2: Treatment and Test of Water Samples:

Treated Water and Method Use

The four-water sample collected from different places as mentioned above in stage 1 is placed in the constructed disinfectant box. As shown in plate 3.2, the constructed box is raped in the interior with aluminium foil is set out under the sun from 10am-6pm. The water samples set under the sun in the constructed box crate were collected in the syringe for every 2hours each for inoculation as mentioned at stage 1 to produce result. The pure cultures obtained were characterized using, colonial, microscopy, indole test, biochemical and sugar fermentation tests, this concluded that E coli stain pink or red rod shape.

Figure 4. Diagram of a constructed solar disinfectant and the samples of water.

Methods

Theory of the Experiment:

The Solar Radiation Equations are:

Solar Disinfection:

When inactivation is done under constant irradiation conditions:
Disinfection kinetics (also for disinfecting agents like chlorine, UV, etc)
Obeys to a first order kinetics, Chick Law.

$$\frac{dN}{dt} = \text{KN} \rightarrow Nt = Noe^{-kt} \quad \text{.....(1)}$$

Nt: concentration of viable microorganisms at time t.
K: constant of disinfection rate
This relationship under solar radiation changes to:

$$\frac{dN}{dt} = \text{KN} \rightarrow Nt = Noe^{-kt} \quad \text{.....(2)}$$
$$Q_{uv} = Q_{uv.n-1} = Q_{uv.n-1} + \Delta t_{n.} UV_{G.n.} A \quad \text{...(3)}$$

Experimental time is used to compare results when lamps are used.

When solar radiation drives the process, we can use the following evaluation parameters:

a) **Q_{uv}:** cumulative UV energy during exposure time per unit of volume of treated water (JI^{-1}).
b) **UV Dose:** UV energy received per unit surface during exposure time (J m-2).

$$Dose_{uv} = UV_{G.n}.\Delta t_n \quad \text{.....(4)}$$

c) **UV Energy**: total UV energy received during exposure time (J).

$$\text{Energy}_{\text{uv}} = \text{UV}_{\text{G.n}}.\text{A}\cdot\Delta\text{t}_{\text{n}} \quad \text{.....(5)}$$

d) Equation for determining the distance and amount of time needed to purify water.

$$l_{(r)} = \frac{pl}{2\pi r} e^{-aer} \quad \text{.....(6)}$$

$l_{(r)}$ = is uv intensity at a distance (mw/cm2)
pl = is uv power emitted per arc length of the sun(mw/cm)
r = is the radical distance from the sun (cm)
ae = base absorption coefficient of the water(1/cm)

Isolation of Escherichia coli (E coli):

Preparation of medial, (MacConkey and Nutrient Agar) MacConkey which is media through which organism are first grown while nutrient agar is a differential media where organisms are sub-cultured. In preparing macconkey,4.8g of MacConkey was weigh and diluted with 100m of silly-water in conical flask, the medial was sterilized in an autoclave for 120C at 15psi for 15 minute allows to cool to a temperature bearable to skin about 15-20m was poured to Petri dish allow to set on a bench, the sample was inoculated and incubated at 37C for 24 hours. After 24 hours the growth was observed and sub-cultured in nutrient Agar after 24 hours the growth was subjected to ground state reaction for configuration.

1. using a sterile inoculating loop, add 1 drop of sterile water to the slide. Prepare a mixed smear of Escherichia coli (G-rod) and Staphylococcus epidermidis (G+ coccus).
2. 2.Air dry and Heat fix.
3. Cover the smear with Crystal Violet (primary stain) for 1 min.
4. Gently wash off the slide with water.
5. Add Gram's Iodine (mordant) for 1 min.
6. Wash with water.
7. Decolorize with 95% ethanol. This is the "tricky" step. Stop decolorizing with alcohol as soon as the purple colour has stopped leaching off the slide (time will vary depending on thickness of smear). Immediately wash with water.
8. Cover the smear with Safranin for 30 seconds.
9. Wash both the top & the bottom of the slide with water.
10. Blot the slide with bibulous paper.
11. Using the 10X objective lens, focus first on the line and then on the smear. Focus the microscope or view the smear using the 100X (oil immersion lens).

Incubator: Laboratory incubators (Genlab) with model (MINI140) AND serial no. 12f076 also with a voltage capacity of 240AC 1PH 50HZ, Load 0.5KW 2AMPS. As shown in Plate 3.3, provide a controlled, contaminant-free environment for safe, reliable work with cell and tissue cultures by regulating conditions such as temperature, humidity, and CO_2. Microbiological incubators, these are used in the laboratory for growing and storing of bacterial cultures.

Autoclave: MODELYXQ-280S, vessel volume 0.018M3patedworking pressure 0.14~0.16Mpa power 2kw/220v 50HZ, As shown in plate 3.4, it is a strong heated container used for chemical reaction and other processes using high pressure and temperature. Autoclave (steam sterilizer), media preparatory and dispensing device for liquid media and microbiological culture media, it sterilizes at 120°C

Wire-loop: -is an instrument for picking growth in the media (MacConkey and nutrient Agar) or it is for transferring microorganism of growth media or for staining slide. The wire loop forms a small loop with diameter of about 5mm. It may be made of platinum or nichrome.

Microscope: -Microscope (GX ML1500) is an optical instrument comprising of an arrangement of lenses that expands the images of the object viewed through it. It is used for the morphological study of very small organisms which are not visible by naked eyes. This microscope is suitable for wide range of laboratories including biological research medical research etc, it combines high quality optics, professional grade stage movement and focusing technology with everything you would expect to find on scientific research grade microscopes costing many times more. The L1500 span signifies great value for money and is suitable for the viewing of almost all slide mount-up samples.

- Broad field oculars, choice of Achromatic or Plan Achromatic objectives.
- Coaxal rough/fine converge system, with tension and control stopper.
- Mechanical stage size:135mmX135mm.
- Height adjustable Abbe condenser, A=1.25.
- Illumination with 6V 20W halogen lamp, adjustable brightness
- Choice of monocular, binocular and trinocular heads

Scale balance: -Scale balance (OHAUS) model PA123 with a maximum capacity of 210g, readability 0.001g and has a power requirement of 8-14.5V-50/60HZ. It is used for establishing the weight or mass of a specimen; scientific balances are midst the more vital pieces of laboratory equipment.

Colony counter: -Model SC6 protected by Stuart-bio-Cote it has 1.7 x magnifiers with 50-100mm dishes the magnifier is available as an optional extra for counting very small colonies. As shown in Plate 3.6, it is a machine used in counting the number of organism growth on a media.

Pyranometer (solar power meter): -solar power meter is a device design to measure the solar radiation falling on a horizontal surface of the earth in watt per square meter (w/m^2). It is a digital solar power meter with a model LI-200R 634BTU/(ft2xh).

RESULTS AND DISCUSSION

Results

The results of the findings are as shown in tables below.

Table 2. Biochemical Test Result for samples of well water

SN	SAMPLE AREA	COLIFORM COUNT	GRAMS REACTION	IND RXN	CIT	OX1	GLU	LAC	SUC	H_2S	GAS	CAT	ORG
1	Campus Area	52	-	+	-	-	+	+	+	-	+	+	Ecoli
2	Wapangha ku	35	-	+	-	-	+	+	+	-	+	+	Ecoli
3	Best Centre	31	-	+	-	-	+	+	+	-	+	+	Ecoli
4	Takum Junction Area	29	-	+	-	-	+	+	+	-	+	+	Ecoli

Table 3. Biochemical Test Result for samples of stream water

SN	SAMPLE AREA	COLIFORM COUNT	GRAMS REACTION	IND RXN	CIT	OX1	GLU	LAC	SUC	H_2S	GAS	CAT	ORG
1	Mission Quarter 1	100	-	+	-	-	+	+	+	-	+	+	Ecoli
2	Mission Quarter 2	139	-	+	-	-	+	+	+	-	+	+	Ecoli
3	Banana Island	98	-	+	-	-	+	+	+	-	+	+	Ecoli

COLIFORM: Klebsiella, Proteus, E coli and Enterobacter aerogenes.

Table 4. Water samples and the isolated bacteria

Samples of both well and stream water	**Bacteria isolated**
Mission Quarter 1	*Staphylococcus aureus, Pseudomonas species, Escherichia coli*
Mission Quarter 2	*Klebsiella species, Salmonella species, Staphylococcus aureus, Escherichia coli*
Banana Island	*Staphylococcus aureus, Pseudomonas species, Escherichia coli, Klebsiella species*
Federal University Campus area	*Staphylococcus aureus, Pseudomonas species, Escherichia coli*
Wapanghaku	*Escherichia coli, Enterobacter species*
Best centre	*Enterococcus, Proteus species, Escherichia coli,*
Takum Junction area	*Escherichia coli, Pseudomonas species, Proteus species*

Escherichia coli Count (Cfu/Ml) for well water at different time Intervals.

Table 5. The reduction of *Escherichia coli* in the well water when exposed to solar radiation.

SN	SAMPLE AREAS	10am – 12pm	12pm – 2pm	2pm – 4pm	4pm – 6pm
1	University Campus area	18	10	7	3
2	Best Centre	5	5	3	0
3	Takum Junction area	22	4	3	0
4	Wapanghaku	27	24	9	6

Escherichia coli Count (Cfu/MI) for stream water at different Time Intervals

Table 6. The reduction of *Escherichia coli* in the stream water when exposed to solar radiation.

SN	SAMPLE AREA	10am – 12pm	12pm – 2pm	2pm – 4pm	4pm – 6pm
1	Mission Quarter 1	**4**	**3**	**1**	**0**
2	Mission Quarter 2	**21**	**5**	**3**	**2**
3	Banana Island	**10**	**6**	**0**	**0**

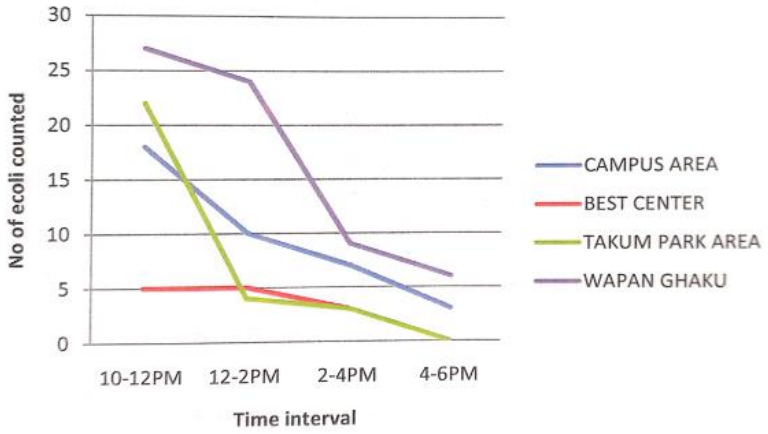

Figure 5. Disinfection of well water

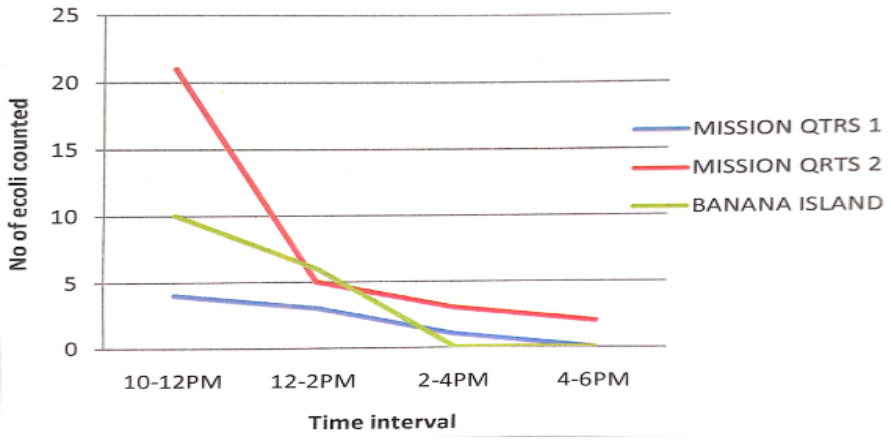

Figure 6. Disinfection of stream water

Table 7. The temperature and solar radiation during the sterilization of the water samples

SN	Time	Temp. (^{0}C) in	Temp. (^{0}C) out	Solar Radiation (w/m^2)
1	10am – 12pm	45	36	200
2	12pm – 2pm	54	44	400
3	2pm – 4pm	56	45	600
4	4pm – 6pm	39	34	800

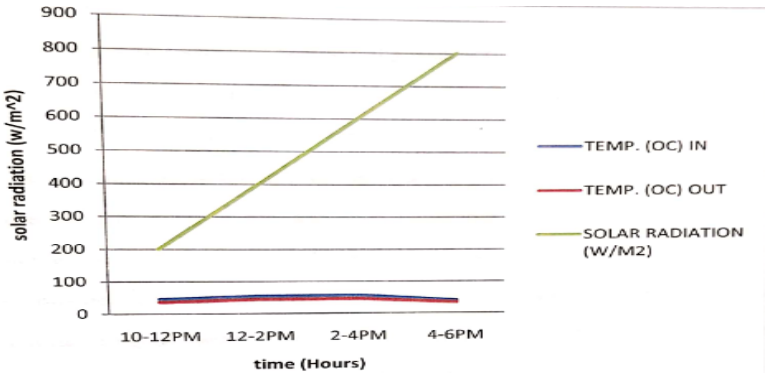

Figure 7. Solar radiation vs Time

DISCUSSION

Each of the water samples was serially exposed under extensive solar radiation(sun) after two hours each ranging from 10am to 6pm.Exactly1 ml of each of the 7 samples of well water and stream water samples was also taken in every hour and inoculated into a molten nutrient agar using pour plate technique. This was properly mixed and allowed to set, and then incubated at 37°C for 24 hours. The resulted colonies were counted, and result expressed as cfu/ml. In the table 1&2 above show the biochemical test used to identify gram positive bacteria and gram negative bacterial. In gram positive where the sign is (+) are in dole test, catalyse test, glucose test, gas, lactose, sulcate all the positive signs shows that there is E coli in the samples otherwise there is no E coli while gram negative (-) are: citrate agar, hydrogen(iv) oxide, oxides, and grams reaction. All the negative sign in various test mention shows the presence of E coli in samples otherwise no E coli present in the sample. The total viable count of bacteria in all the samples ranged from 12 cfu/ml (MQRTS) to 139 cfu/ml (MQRTS) for both well and stream water (Table 2 and 3).

Table 4 presented the bacteria isolated from various samples. The result showed that Escherichia coli was isolated from samples Mission quarters, Mission quarters, Banana Island, Federal University Campus Area, Wapanghaku, Best Centre, Takum Junction Area. Contamination of water sources have been reported by several authors as a medium of disease outbreak and spread in developing countries and rural areas [19] and [20]. In Wukari where the present study was carried out, treated pipe-borne water and public water supply is inexistent. Alternatively, the populace uses drilling water (boreholes) and wells (for individuals that cannot afford the cost of digging boreholes) for drinking and domestic purposes. In the present study, the total viable bacterial count which ranged from 12 cfu/ml to139 cfu/ml was high and less than the recommended limit of<500 cfu/ml. This observation is like the work of Ngwa and Chrysanthus [21] on well water sources in the Bambui student residential area, who reported viable count of bacteria in the range of 0.2-7.3x104 cfu/ml. The high bacteria count is an indication that the various water sources are high contaminated bacteria which could be of public health concern. The high values could be attributed to run-off water that enters some of the wells during raining seasons and particles from the environment which gain access into the wells from time to time. These values are high when compared with the permissible MPN index by world Health Organization of 10 coliforms/100ml of water sample. This observation is consistent with the reports of Krishnan et al. [22], Ngwa and Chrysanthus [21] and Gambo et al. [23] who reported high coliform counts in all well and borehole water analysed. The high number of total coliforms could be due to inadequate maintenance of the well water as many of the wells are uncovered. It can also be attributed to percolation of sewage into the ground water sources [23].

CONCLUSION

This project well water disinfection using solar energy is a project aimed to enhance the purification of water with the aid of solar radiation. Solar water disinfection, in short SODIS, is a type of portable water purification that uses solar energy to make biologically contaminated (e.g., bacteria, viruses, protozoa and worms) water safe to drink. Well water is the water drawn from a boring pit few meters below the earth surface using bucket, the world health organization (WHO) estimates that about a huge number of people worldwide lack access to clean water. Having access to clean water supply is essential not only to prevent fatal dehydration but also for sanitation purposes. Isolation of Escherichia coli (E coli) Preparation of medial (MacConkey and nutrient agar), Biochemical test used to identify gram positive bacteria and gram negative bacterial. In gram positive where the sign is (+) all the positive signs shows that there is E coli in the samples otherwise there is no E coli while gram negative (-) are: citrate agar, hydrogen (iv) oxide, oxides, and grams reaction. All the negative sign in various test mention shows the presence of E coli in samples otherwise no E coli present in the sample.

It may be concluded that the aim and objectives of the project have been met by successfully constructing a solar disinfectant and disinfecting well water. The data collected during the analysis demonstration area and monitoring at user level confirmed that SODIS is a reliable method for drinking water disinfection at household level. After years of research and field testing, the challenge of reducing the incidence of water-borne diseases through SODIS use is now lying in the hands of the institutions and field workers in charge of hygiene education and sanitation programs. Through appropriate diffusion of the information, intensive training of users and follow-up, people will have Access to a simple and affordable alternative to improve the microbiological quality of their drinking water at household level.

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