Performance Evaluation of a Modified SODIS under Sub-Tropical Climate Condition in Bangladesh

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PROJECT REPORT APPROVAL

The thesis titled “Performance Evaluation of a Modified SODIS under Sub-Tropical Climate Condition in Bangladesh” submitted by Mastura Morshed Nawmi and Nafisa Anjum Rimi with St. ID: 180051201 and 180051202 has been found as satisfactory and accepted as partial fulfillment of the requirement for the Degree, Bachelor of Science in Civil Engineering.

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DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Professor Dr. Md. Rezaul Karim and this work has not been submitted elsewhere for any purpose (except for publication).

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DEDICATION

We dedicate our work humbly to everyone who has been directly and indirectly involved with it, especially our parents, our respected teachers and friends. We specially thank our supervisor Professor Dr. Md. Rezaul Karim sir without whose support, dedication and attention our work would not be possible. We also thank our teacher Habibur Rahman Bejoy sir for his unwavering support.

We will always remember our friends who has been with us, we will always appreciate what they have done.

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Abstract

The World Health Organization (WHO) has acknowledged solar disinfection (SODIS) as a low-cost, efficient, sustainable, and simple approach for getting rid of certain germs in drinking water. According to studies, SODIS' primary drawbacks are longer exposure times (>6h), inefficiency in the monsoon and winter months, and the regeneration of microorganisms following treatment. To get around these restrictions, this study used test water and drinking water collected from restaurants, slums, and household areas in accordance with the WHO protocol during the monsoon and winter seasons in Bangladesh's subtropical climate to evaluate the performance of a modified SODIS with a photo catalyst (H_2O_2). Regression analysis was also carried out to forecast the rate of bacterial disinfection utilizing the modified SODIS with H_2O_2. The WHO protocol was followed in the preparation of two different test waters. Reactors with a 500 ml capacity made of polyethylene terephthalate (PET) bottles and plastic bags were used for the SODIS experiment. In order to each PET or plastic bag (PB), 5 cc of H_2O_2 was added. Six PET or PB with test water or collected drinking water samples were utilized in each batch, and they were exposed to sunlight using a made-up SODIS chamber for six hours during the monsoon season (June–October, 2022) and the winter season (November–February, 2023) respectively. The physicochemical and bacteriological water quality parameters were measured prior to the SODIS experiment. Along with bacteriological characteristics like Escherichia coli (E. coli) tests, physicochemical parameters including dissolved oxygen (DO), electrical conductivity (EC), pH, turbidity, and water temperature were evaluated in every test. One sample was taken for physicochemical and bacterial analysis during each hour of the SODIS experiment, and the sun irradiance was measured every 1 min. To test the microbes' potential for regrowth, the SODIS-treated water was left at room temperature in the dark for 12 and 24 hours after being treated for 6 hours. To test the improved SODIS, drinking water samples were also taken from Dhaka City eateries, slums, and residential establishments. The variations in the physicochemical parameters before and after SODIS demonstrated that there were no notable changes other than in the EC values. The effectiveness of modified SODIS with H2O2 shows that the PET bottle only needed 2 hours to inactivate germs, while PB only needed one hour during the monsoon season to obtain a 6.7 log reduction value (LRV). However, during the winter, it took 2 hours for bacteria in a PET bottle and PB to become inactive, resulting in a 5.49 LRV. After the 12 and 24 hours post-SODIS periods in the monsoon and winter seasons, respectively, there was no regrowth. Based on microbial inactivation (LRV >4), SODIS with H2O2 was deemed to be "Highly Protective" in performance. With an R2 value of 0.95-0.98, the Weibull bacterial inactivation model matches the data of PET bottles and PB in the monsoon and winter seasons well. The minimum and maximum safe exposure times for achieving the four LRV were 1 and 2 hours, respectively. Regression analysis showed that PB (TW-1) with an R2 value of 0.79 (79%), where the equation coefficients are turbidity, water temperature, solar irradiation, and DO, had the highest degree of accuracy. According to regression analysis, the rate of disinfection increased with rising water temperature, solar irradiation, and DO and reduced with rising turbidity. The statistical analysis findings from the regression analysis also showed how well the model suited the data from this investigation. Drinking water samples were taken from eateries, slums, and residential areas. The findings of the water parameter tests show that the majority of the water was microbially contaminated and included iron. The application of the modified SODIS with H2O2 in comparison to the traditional SODIS shows that the modified SODIS functions better and does not experience regrowth. The findings of this investigation are consistent with the literature on SODIS for inactivating bacteria. If properly promoted, SODIS has the potential to be a viable technology for drinking safe water and giving access to water in water-stressed parts of Bangladesh and other developing countries. The findings of this study will enable people in Bangladesh and other developing nations to recognize the usefulness of SODIS and use it for potable water.

Keywords: Solar Radiation, UV-A, SODIS, HWT , Low-Cost, Drinking Water, Poverty, LRV, E.Coli

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1 Introduction

In 2022, the world's population is projected to reach 8 billion, providing significant issues for water shortages and access to drinkable water on a worldwide scale (UN, 2022). Out of 8 billion people, more than 2 billion live in countries with water scarcity, and 785 million people lack access to a basic and safe water supply (UNICEF and WHO, 2022a). These concerns demand immediate attention. Although the Sustainable Development Goal 6.1 of the United Nations intends to provide universal and equitable access to safe and affordable drinking water for all by 2030, pandemics, climate change, and overpopulation are preventing it from being achieved. Cholera, diarrhoea, dysentery, hepatitis A, polio, and typhoid are just a few of the water-borne illnesses that are brought on by unsafe drinking water. Only diarrhoea alone causes 829,000 global fatalities, 90% of which are children under the age of five. Furthermore, a whopping 2 billion people worldwide consume feces-tainted water, the majority of whom reside in developing nations, particularly those with low incomes (WHO, 2022a). The population of these nations is compelled to rely on highly microbial contaminated water from shallow wells, lakes, rivers, and springs due to the inadequacy of conventional drinking water treatment and delivery networks (Chaque et al., 2021). It is possible to address this problem by promoting Household Water Treatment (HWT) solutions that are reasonable in cost, simple to use, and sustainable (Hunter, 2009; Meierhofer and Landolt, 2009). There are many HWT interventions available, including filtering, UV disinfection, chemical disinfection, chlorination, and solar disinfection (SODIS). According to numerous studies conducted in underdeveloped nations (Brockliss et al., 2022; Figueredo-Fernández et al., 2017; McGuigan et al., 2012; WHO, 2011), SODIS is a simple, low-cost, and sustainable intervention.

Water is simply placed in a clean PET bottle, plastic bag, or transparent glass, shaken to increase dissolved oxygen (DO), and exposed to direct sunlight for 6 hours on a sunny day; on a cloudy day, it may take 48 or 2 days to completely inactivate microorganisms (Meierhofer and Wegelin, 2002; Oates et al., 2003; McGuigan et al., 2012; Karim et al., 2021). According to McGuigan et al. (2012) and Meierhofer and Wegelin (2002), sun irradiation and water temperatures above 45°C have a powerful synergistic effect that causes microbial inactivation. Microorganisms' deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) is directly absorbed by UVB light (280–320 nm), which inactivates them (Mbonimpa et al., 2012). Indirect inactivation of 70% is caused by reactive oxygen species (ROS), which are produced as a result of the absorption of visible and UVA light (>320 nm) by endogenous chromophores acting as sensitizers (CastroAlférez et al., 2017). The lipids and proteins of microbes are destroyed by ROS, which also changes membrane permeability and causes DNA breaks (Berney, 2006). SODIS has been demonstrated to be effective against all types of microbes, including bacteria (E. coli, Salmonella typhimurium, Pseudomonas aeruginosa, Campylobacter jejuni, Vibrio cholera, etc.), fungi (Fusarium solani), viruses (Bacteriofage f2, Polio, Rota, and Noro, etc.), and protozoa (Giardia According to McGuigan et al. (2012), Heaselgrave and Kilvington (2010), and PoloLópez et al. (2020)).

Even though SODIS is highly recommended, it has a number of disadvantages, such as the need for high levels of solar irradiation and higher water temperatures, which makes it highly climate dependent; it requires a longer exposure time to disinfect the water in the monsoon and winter seasons; and it has a limited capacity for water treatment. Furthermore, following the application of SODIS, microorganisms also multiply again (Mäusezahl et al., 2009; Giannakis et al., 2014, 2015; McGuigan et al., 2012; Martínez-García et al., 2020; Reyneke et al., 2020; Rosa e Silva et al., 2022). As a result, longer disinfection times and the regeneration of microorganisms after SODIS are now two of the largest barriers to SODIS's broad adoption. Recently, a variety of additives have been added to SODIS to speed up the process and increase disinfection effectiveness by producing reactive oxygen species (ROS) like the hydroxyl (•OH) radical, superoxide, hydrogen peroxide, and singlet oxygen. Reactive oxygen species (ROS), which are produced during photo inactivation of E. coli, are primarily produced by oxygen, and the addition of H2O2 improves this photo inactivation. (Reed,1997; Fisher, 2004; Rincón and Pulgarin, 2004). In addition, Hoerter et al. (1996) discovered that an internal Fenton-like mechanism caused E. coli to be photoinactivated when H2O2 was present. The iron-dependent breakdown of H2O2 shown in Equation 1.1 characterizes the photo-Fenton process (Fisher et al., 2008).This photo-Fenton process is the most successful at generating reactive oxygen species (ROS) and eliminating microorganisms when compared to other additive addition methods (Villar-Navarro et al., 2019; Garcia-Fernández et al., 2012). The Haber-Weiss reaction, which breaks down hydroxyl radicals (•OH) through dissolved iron ions in water, causes the Fenton process (Haber et al., 1934; Sychev et al., 1995). By diffusing H2O2 across the cell membrane, the combined effects of solar light and H2O2 reacting with the dissolved irons in water lead to oxidative stress and the inactivation of microorganisms (Halliwell and Gutteridgde, 1999; Polo-López et al., 2011). Equations 1.1 and 1.2 illustrate how the Fenton process uses principally Fe2+/Fe3+ found in water and hydrogen peroxide added to react quickly and generate •OH radicals that oxidize bacteria' DNA, proteins, and cell membranes, leading to their inactivation. (García-Fernández et al., 2012; Rincón and Pulgarin, 2007; Sciacca et al., 2010).
Fe2+ + H2O2 → Fe3+ + OH− +• OH (k = 63 L mol−1 s−1) (1.1)
Fe3+ + H2O2 → Fe2+ + HO2 • +H + (k = 3.1 × 10−3 L mol−1 s−1) (1.2)
Bangladesh is a growing country with a concerning population growth rate. A recent study found that 41% of the improved water sources included excrement and that 68.3 million people do not have access to

drinkable water(World Bank, 2018; UNICEF, 2021). A low-cost, sustainable system like SODIS could be a great way to prevent the usage of contaminated water in a subtropical country like Bangladesh where solar exposure is high throughout the year. The majority of people in this nation rely on groundwater as their primary supply of drinkable water, and the average iron level in that water is 0.91 mg/l (Stewart et al., 2019). This likely iron content in the water could cause a photo-Fenton reaction when mixed with H2O2 and sunlight. Islam et al. (2015) and Karim et al. (2021) have both conducted recent studies that show the value of SODIS in both laboratory and field settings.

However, the main problem revealed by these studies is that the disinfection duration is greater than 6 hours during the monsoon and winter seasons, and the regrowth of bacteria is common after the SODIS treatment. There is a clear need for research because no studies have been done in Bangladesh to increase the efficiency of SODIS for shortening disinfection times and preventing microbial regrowth throughout the monsoon and winter seasons. In this study, the usage of H2O2 was assessed in order to increase the efficacy of SODIS in terms of reducing disinfection time and microbial regrowth. Additionally, the capability of the photo-Fenton technique to eradicate E. coli was evaluated. These results can be utilized as scientific proof to support the modified SODIS as an HWT strategy for evaluating safe drinking water supplies in communities with limited water resources.

1.2 Objectives

The following are the study's particular objectives:

1. To Assess the Effectiveness of Improved SODIS under Monsoon and Winter Weather Conditions using Test water and Drinking water used in Field conditions.

2. To Find the Regrowth Potential of Microorganisms after 12 hours and 24 hours of Disinfection.

3. To develop a regression model to predict the disinfection rate of SODIS under different climate conditions.

1.3 Scope of the research

1. Development of a modified SODIS using hydrogen peroxide.

2. Two types of water (Test water, Drinking water collected from households, restaurants and slums) were used to evaluate the effectiveness of the modified SODIS with H_2O_2 during the monsoon and winter seasons.

3. Regrowth potential evaluation of the modified SODIS with H_2O_2.

4. Regression analysis was used to predict the disinfection rate of the modified SODIS with H_2O_2.

5. Promotional strategy for the modified SODIS for use in the field in rural and urban areas with questionable water supplies.

1.4 Thesis layout

The thesis includes five chapters. The relevant literature review, the modified methodology, the modified SODIS with photo catalyst, and the study's findings are discussed here. This study also includes the references.

The background, goals, scope, and contribution of this work are discussed in **Chapter 1**.

Chapter 2 discusses the conventional SODIS system's disinfection mechanism, its limitations, how effective it is against different microorganisms, how weather and climate affect SODIS, the various established SODIS enhancement steps, and the effects of SODIS on human health.

Chapter 3 describes how to build a SODIS prototype using inexpensive, locally accessible materials, the processes of a lab experiment, the results of water parameter measurements, locations of data collecting points, bacterial and regression models, and the statistical analysis used in this study.

The results of the modified SODIS's regrowth potential, along with bacterial inactivation models and regression analysis for forecasting the disinfection rate, are presented in **Chapter 4** along with performance analysis of the modified SODIS carried out under laboratory conditions (using test water) in accordance with WHO guidelines during the rainy and winter seasons with PET and plastic bags as containers. Cost analysis was performed for the installation of the updated SODIS.

The experimental conclusions using laboratory and water collected from restaurants, slums, and homes are presented in **Chapter 5**, along with the potential areas for further research.

2. Literature Review:

This chapter is a review of the literature on the current state of SODIS mechanisms, efficacy, enhancement, the influence of climate and weather, impact on health, benefit, and harm, as well as guidelines for evaluating the performance of various HWT options thoroughly in accordance with the most recent studies.

2.1 Solar Disinfection (SODIS)

Solar water disinfection, or SODIS, is one of many useful HWT technologies that can be used to purify drinking water. Because it has been embraced in so many different countries, it is claimed that millions of individuals have received training on how to use it (Luzi et al., 2016). Hollaender conducted the first quantitative study on the near-UV inactivation of E. coli in 1943 (Hollaender, 1943), and Lukiesh demonstrated that E. coli may be killed by sunlight in 1946 (Luckiesh, 1946). The first quantitative research on how the sun can purify drinking water and oral rehydration solutions were conducted in the 1980s by Acra et al. at the American University of Beirut in Lebanon (Acra et al., 1980; Acra, 1984). According to the findings of this study, Escherichia coli is to be utilized as an indicator organism for disinfection. Since then, several research teams have examined the SODIS technique, with the Swiss Federal Institute of Environmental Science and Technology (Wegelin et al., 1994) being a leader in many parts of the applied study and dissemination of useful SODIS material. The WHO supports the use of sun disinfection (SODIS) to produce potable water. It has been promoted both independently and as a component of larger initiatives like HWTS (Household Water Treatment and Safe Storage) or WASH (Water, Sanitation, and Hygiene). The majority of SODIS promotion focuses on acts intended to modify the behavior of the target group because the execution of the strategy only needs sunshine and PET bottles. The efficiency of SODIS depends on how simple it is to use: to purify water, simply fill a clear container with the available water and leave it in the sun for one day (under normal irradiation conditions) or two days (under cloudy skies) (McGuigan et al., 2012) .

A wide variety of water-borne pathogens, such as E. coli, Salmonella, Vibrio cholerae, Enterococcus faecalis, Bacteriophage MS2, Hepatitis A virus, and Cryptosporidium parvum, have also been proven to be resistant to SODIS (Sansaniwal, 2019). Contaminated water is a leading cause of illness, notably diarrhea and other gastrointestinal problems, in rural areas where water supplies are contaminated and sanitation is poor (Caslake, 2004). Laboratory and field studies have demonstrated that this method is successful at killing waterborne germs.

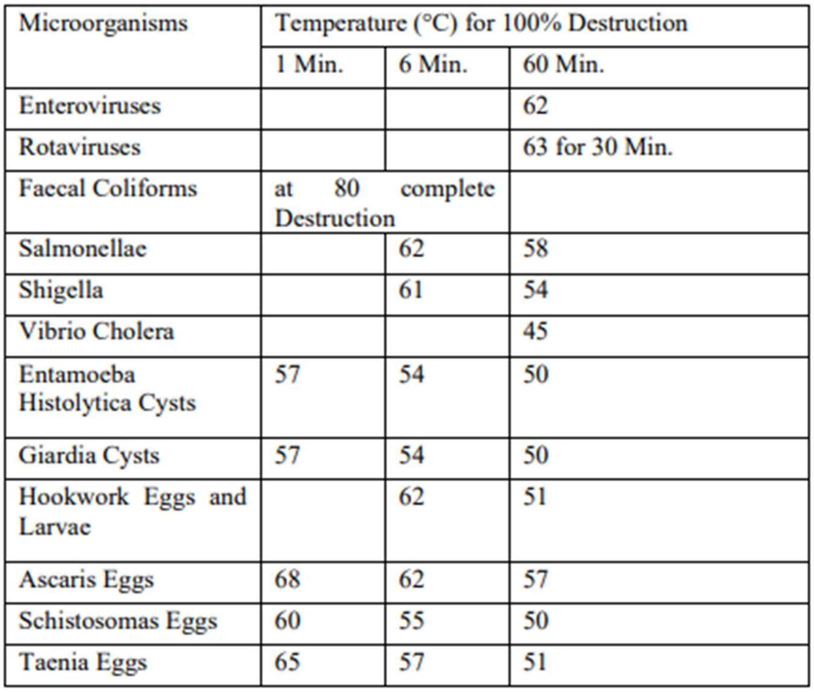
(Wegelin et al., 1994; Sommer et al., 1997; McGuigan et al., 1998; Oates et al., 2003; Dejung et al., 2007; Graf et al., 2010; Figueredo-Fernández et al., 2017).

2.2 Disinfection Mechanism of Sunlight

Water pathogens can be eliminated by directly exposing them to sunshine, which is what solar water disinfection achieves. It disinfects drinking water by working on the top layer of bodies of water. UV (ultraviolet), visible (visible), and infrared (IR) waves are examples of radiation that reaches the Earth's surface. UV-B, UV-A, and maybe less visible spectrum radiation produces active or passive disruption to the organisms' proteins and DNA, rendering them inactive during sun disinfection. SODIS disinfects water by utilizing two properties of sunlight.

2.3 Temperature Effect

Solar disinfection takes time to achieve the desired log reduction. This time is determined by a number of factors. The most critical elements that affect SODIS efficiency are solar irradiance and energy dose, wavelength, water temperature during treatment, turbidity, salt content, dissolved oxygen, dissolved organic matter in the polluted water, and the type of the microorganisms (Webb and Brown, 1979; Moss and Smith, 1981; Reed, 1997; McGuigan et al., 1998; Ubomba-Jaswa et al., 2009a; Ubomba- Solic and Krstulovic,1992). According to studies, after the water temperature hits 45°C, the radiation and heat from the water combine to eradicate any microorganisms present (McGuigan et al. 2012). Temperatures of 60-70°C have previously been observed in laboratory-controlled biology studies for the thermal deactivation of E. coli without UV (Collis O'Neill and Middelberg 1995). Solar cookers, which typically heat water to temperatures around 65°C without the use of UV radiation, have also been the focus of water purification research (Ciochetti and Metcalf 1984). The use of nanoparticles for thermal deactivation, the focus of recent novel work, was found to be effective, as water temperatures were not considerably changed. In doing so, they absorb photons in the UV-A and visible bands, becoming excited and producing highly reactive molecules such as singlet oxygen and hydroperoxyl radicals, which impede cell reproduction and kill microorganisms (Nelson et al. 2018). Furthermore, infrared light with a wavelength of roughly 800 nm can raise the temperature of a liquid and kill any heat-sensitive microorganisms. Marques et al. (2013) confirmed this by measuring the temperature of irradiated water, which reached 50°C and killed 99% of E. coli. Furthermore, a recent study found that the inactivation rate was higher in water with a temperature of 6°C than in water with a temperature of 22°C (Villar-Navarro et al. 2021). While very turbid waters can be treated, temperatures of at least 55°C are required (Joyce et al. 1996). At these temperatures and turbidities, only pasteurization (heat treatments) may inactivate germs. McGuigan et al. (2008) revealed that 99% inactivation of E. coli occurred only 1 cm into the optical path, even in highly turbid water (200 NTU).



Microorganisms	Temperature (°C) for 100% Destruction		
	1 Min.	6 Min.	60 Min.
Enteroviruses			62
Rotaviruses			63 for 30 Min.
Faecal Coliforms	at 80 complete Destruction		
Salmonellae		62	58
Shigella		61	54
Vibrio Cholera			45
Entamoeba Histolytica Cysts	57	54	50
Giardia Cysts	57	54	50
Hookwork Eggs and Larvae		62	51
Ascaris Eggs	68	62	57
Schistosomas Eggs	60	55	50
Taenia Eggs	65	57	51

Table 1: Effect of Temperature on Various Microorganisms

Microorganisms and other pathogens are killed by heat. The table shows the temperature and time required to kill several species of bacteria. Boiling water is not required to kill 99.9% of bacteria and other pathogens, as illustrated here.

2.4 Synergetic Effect of UVA Radiation and Temperature

The method by which solar radiation kills bacteria is usually cited as the combination of solar ultraviolet (UV) light and low-level infrared heating of the water (McGuigan et al., 1998; Berney et al., 2006a). Synergistic effects are already apparent in the inactivation process at 45°C, and they become stronger as the temperature rises (Vivar et al. 2017). Wegelin et al. (1994) found that temperatures between 20 and 40°C do not kill bacteria, but that beyond 45°C, UV-A and visible light have a synergistic effect. Water must be heated to at least 50°C to destroy bacteria like E. coli. At 50° water temperature, a synergistic effect between UV-A radiation and temperature occurs, requiring just 140 W.h/m2 of UV-A radiation to achieve a 3-log reduction in fecal coliforms (Wegelin et al. 1994).

2.5 Effect of SODIS on Pathogen

Resistance to UV-A irradiation varies greatly amongst pathogen types. A byproduct of the SODIS process is UV-B radiation, which has little influence on the SODIS process with PET bottles but has a significant impact on several viruses. When compared to viruses and protozoa, there is less variation in sun radiation resistance among different species of hazardous bacteria.

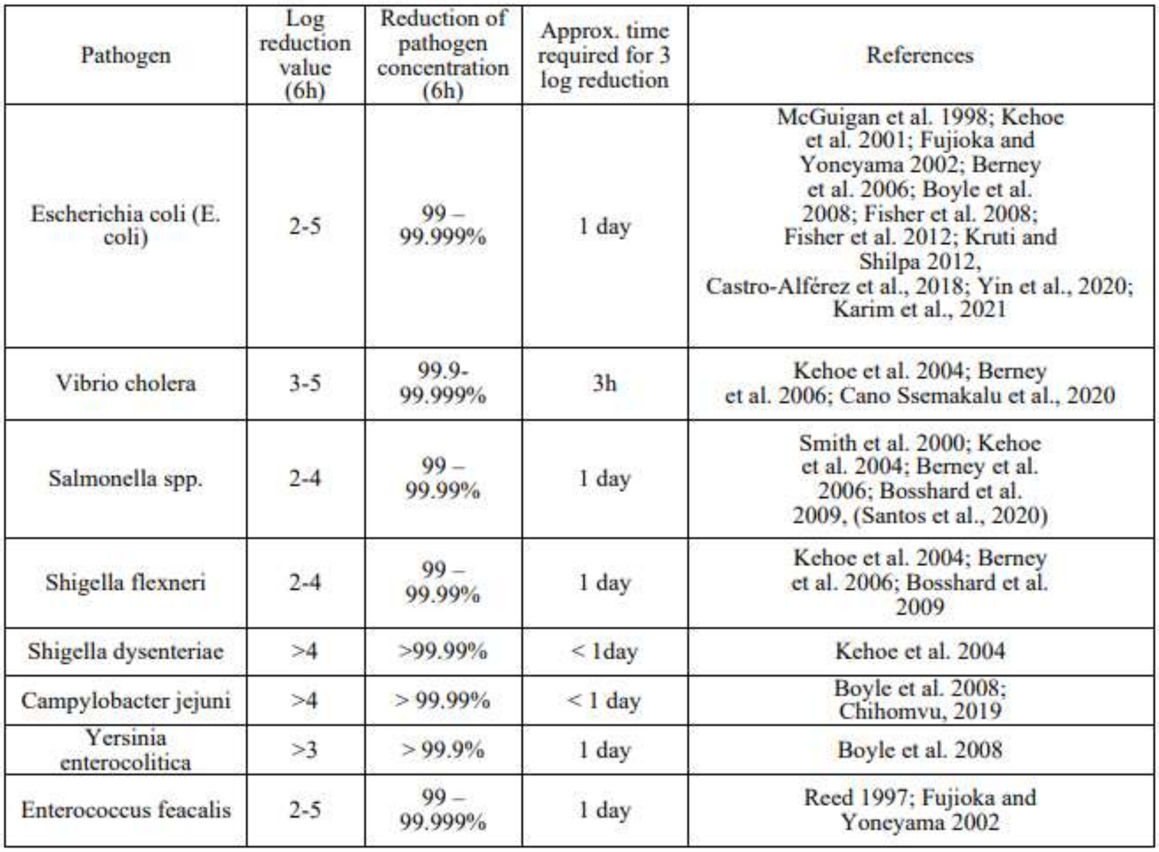
Human pathogens have evolved to persist in the dark, humid surroundings and 36°C to 37°C temperatures present in the human intestines. After they are liberated, the diseases are particularly sensitive to the harsh environment. They have no UV light protection and wilt under even modestly heated temperatures. This means that pathogens can be rendered harmless by exposing them to either heat or ultraviolet light. The effectiveness of SODIS against various bacteria is discussed further below.

2.6 Bacteria

Cholera and bacterial dysentery are two of the most serious types of diarrhea caused by bacteria. On an average day in the tropics or subtropics, SODIS reduces the number of these diseases by orders of magnitude. Table 2.2 of the scientific literature shows the average eradication rates for various types of dangerous bacteria.

According to the literature on E. coli, bacteria obtained from sewage tend to be more resistant to solar radiation than bacteria produced in the lab (for example, Fisher et al. 2012).

Because some coliforms are more resistant to sun radiation than others, studies of SODIS inactivation based on total coliform concentrations are likely to underestimate the efficiency against harmful pathogens.



Pathogen	Log reduction value (6h)	Reduction of pathogen concentration (6h)	Approx. time required for 3 log reduction	References
Escherichia coli (E. coli)	2-5	99 – 99.999%	1 day	McGuigan et al. 1998; Kehoe et al. 2001; Fujioka and Yoneyama 2002; Berney et al. 2006; Boyle et al. 2008; Fisher et al. 2008; Fisher et al. 2012; Kruti and Shilpa 2012, Castro-Alférez et al., 2018; Yin et al., 2020; Karim et al., 2021
Vibrio cholera	3-5	99.9- 99.999%	3h	Kehoe et al. 2004; Berney et al. 2006; Cano Ssemakalu et al., 2020
Salmonella spp.	2-4	99 – 99.99%	1 day	Smith et al. 2000; Kehoe et al. 2004; Berney et al. 2006; Bosshard et al. 2009, (Santos et al., 2020)
Shigella flexneri	2-4	99 – 99.99%	1 day	Kehoe et al. 2004; Berney et al. 2006; Bosshard et al. 2009
Shigella dysenteriae	>4	>99.99%	< 1day	Kehoe et al. 2004
Campylobacter jejuni	>4	> 99.99%	< 1 day	Boyle et al. 2008; Chihomvu, 2019
Yersinia enterocolitica	>3	> 99.9%	1 day	Boyle et al. 2008
Enterococcus feacalis	2-5	99 – 99.999%	1 day	Reed 1997; Fujioka and Yoneyama 2002

Table 2: Inactivation rate of Various Bacteria

2.6 Virus

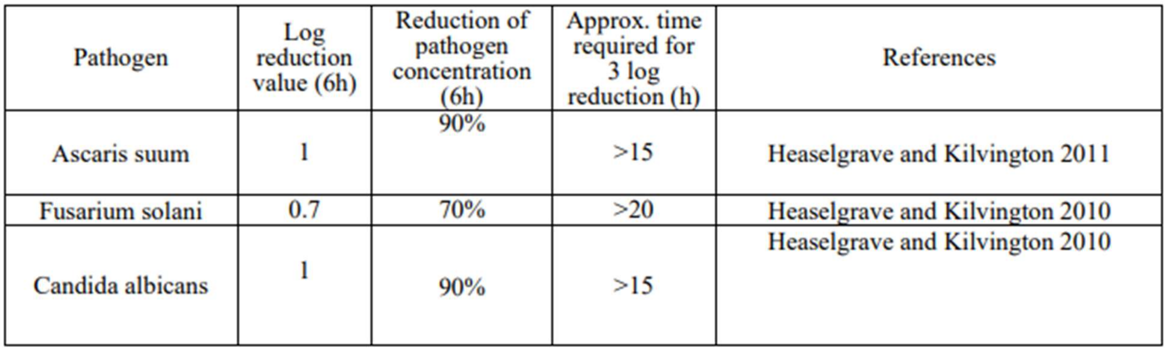
Water can spread rotavirus, caliciviruses, coxsackievirus, enterovirus (e.g., poliovirus, echovirus), adenovirus, hepatitis A and E virus, coronavirus, and astrocystis virus (Susana 2009). Viruses produce a significant share of all diarrheal illnesses. Although rotavirus, the virus that causes the majority of viral diarrhea in children, can be transmitted through contaminated water, evidence indicates that it is transmitted mostly through contaminated hands or other surfaces (Percival et al., 2004). Because contagious viruses are more difficult to quantify, evidence on SODIS's success in eliminating viruses is scarcer than data on its effectiveness in eliminating bacteria. Furthermore, not all publicly available SODIS research follows to the normal SODIS process in PET bottles since they employ bacteriophages as human virus models rather than true pathogens and non-standard experimental setups (e.g., not eliminating UVB rays).

A recent study found that the rate of virus inactivation in PET containers is significantly dependent on the virus type and water composition (Dionisio Calado 2013). Oxidant-sensitive viruses (echovirus and bacteriophage MS2) were effectively inactivated in tap water (4 log eradication in 6 h), whereas in India, inactivation was significantly slower.

Treatment-resistant viruses were inactivated at much smaller percentages across the board. In this study, higher temperatures were found to be significantly more effective in disinfecting viruses.

2.7 Other microorganisms

Table 2.5 summarizes research on SODIS's efficacy against various infections. The given data show that only under standard SODIS settings are elimination values in the range of 1 LRV (2010) expected. When compared to bacteria, viruses, and protozoa, these microorganisms represent small contributors to the health burden of aquatic diseases.



Pathogen	Log reduction value (6h)	Reduction of pathogen concentration (6h)	Approx. time required for 3 log reduction (h)	References
Ascaris suum	1	90%	>15	Heaselgrave and Kilvington 2011
Fusarium solani	0.7	70%	>20	Heaselgrave and Kilvington 2010
Candida albicans	1	90%	>15	Heaselgrave and Kilvington 2010

Table 3: Inactivation rate of other microorganisms

2.8 Efficiency of SODIS

Several studies examined the efficacy of SODIS across a spectrum of water quality, container types, and environmental conditions using pathogens with differing levels of virulence. The efficiency of the application of laboratory ideas and findings to field studies is briefly reviewed.

2.9 Turbidity Effect

As a result, SODIS is less successful at cleaning muddy water. Before using SODIS, it is suggested that a turbidity level of no more than 30 NTU be maintained (Meierhofer and Wegelin, 2002). Some dissolved organic chemicals absorb visible light and act as water colorants, whereas others have no effect on the look of the water. Furthermore, Kehoe et al. (2001) showed that in high turbidity waters (> 100 NTU), the UV radiation required to achieve complete inactivation increased, but was still achievable with exposures of up to 8.5 h.

They concluded that water with an NTU value greater than 300 may require pretreatment by filtering or decanting before SODIS treatment. Keogh et al. (2015) found that UV doses of 250, 730, and 750 kJ/m2 achieved a 4-log reduction in E. coli in 19-L polycarbonate containers with low turbidity water at PSA in Bahrain and India.

Dessie et al. (2014) found that increasing turbidity affects disinfection efficacy considerably. The authors indicate that after 3 hours of exposure to the substance, 0.93 log units of turbidity were removed from water at

2 NTU, but just 0.05 log units were removed from water at 81 NTU. As turbidity increased from 0 to 200 NTU, E. coli inactivation decreased from 5 log units to 1 log (Amirsoleimani and Brion, 2021). They also discovered that turbidity levels of 30 and 200 NTU resulted in approximately 1 log of removal of E. coli concentrations, whereas turbidity levels of 0 NTU resulted in the greatest inactivation (almost 5.03 logs of elimination as bacterial counts were below detection) of 95.31 and 89.04%, respectively. The temperature climbed as turbidity increased because the bactericidal effects of sunlight were inhibited by clay particles, showing that solar insolation had changed from ultraviolet (UV) to infrared (IR). However, if SODIS is to be used effectively, turbidity must be reduced before treatment. SODIS's efficiency is diminished since UV light is completely absorbed after a few centimeters in severely murky waters (Gómez-Couso et al. 2009; McGuigan et al. 1998). This implies that filtering turbid waters prior to exposure is strongly advised. When turbidity levels above 30 NTU, SODIS performance suffers greatly. Water with increased turbidity requires preparatory treatment.

2.10 Effect of Dissolved Oxygen

SODIS performs better in water with this type of oxygen. These reactive compounds react with pathogen cell structures and kill them (Reed, 1997). Aeration of the water can be accomplished by shaking the 34-filled bottle for about 20 seconds before filling it completely and exposing it to the sun (Meierhofer and Wegelin, 2002). Increased dissolved oxygen content promotes the production of reactive oxygen species (ROS), which are responsible for oxidative disinfection processes (Reed et al. 1997). It is critical to leave the bottles in one location once they have been placed in the sun, as moving them about too much will reduce the effectiveness of the sunlight exposure (Kehoe et al., 2001). The disinfection rate for E. coli and Enterococcus faecalis is almost half that of full oxygen saturation at 50% oxygen saturation (Reed, 1997). 2.4.1.3 Effect of color

According to experiments, when there is a lot of color in the water, the time it takes to destroy the pathogens rises (Reed, 1997).

2.11 Water temperature Effect

At temperatures ranging from 45°C (Vibrio cholerae) to 63°C (Enteroviruses), pathogens can be eliminated in 60 minutes (Berney et al. 2006). SODIS's efficiency increases considerably as temperature rises, even below pasteurization limits. Below 45°C, inactivation rates are slightly and roughly linearly temperature dependent (Wegelin et al. 1994; Fisher et al. 2008). Wegelin et al. (1994) discovered that treating at 50°C can reduce the required irradiation dose and/or exposure length by up to two-thirds, resulting in a three-log difference in pathogen reduction compared to the calculated sum of radiation and heat effects (Theitler et al. 2012). This means that under ideal conditions (high temperatures and sufficient radiation), full disinfection can be achieved in less than the specified day (6 hours minimum). However, users are unaware of the temperature of the water contained within SODIS bottles. As a result, even if the irradiation parameters and temperature appear to be acceptable, it is not recommended to shorten the exposure time. Also, if the bottles are to be placed on a dark surface to enhance the heat effect, it is not recommended to shorten the exposure time. According to field tests conducted in the north-west plateau of China and the highlands of Bolivia (UNICEF, 2005), countries with cold or mild temperatures are equally suited for SODIS if sufficient sun exposure is available.

2.12 Material and Shape of Container

The way bacteria are destroyed in SODIS applications is heavily influenced by the container's material and form, both of which are critical. Because diverse material and shape features contribute to improve the process, these properties should be understood and utilised in the SODIS application.

2.13 Plastic bottles

Many types of clear plastic are effective at transmitting both ultraviolet (UV-A) and visible (visible) light. Plastic bottles are often made from PET (Poly Ethylene Terephthalate) or PVC (Poly Vinyl Chloride). Both contain additives, such as UV-stabilizers, that preserve them and their contents from oxidation and UV radiation and increase their stability.

It is recommended that PET bottles be used rather than PVC bottles because PET has far less additives than PVC bottles. Field testing reveal that clear PET bottles with a capacity of 2 liters are the best way to deliver SODIS. In lab studies, both returnable and one-way bottles perform well, but one-way bottles perform better since they allow more UV radiation through. One-way bottle transmission coefficients do not change noticeably over time. Because UV light does not travel through colored bottles, they are not suggested for SODIS(Wegelin, 2000; Quispe, 2000).

2.14 Plastic bag

SODIS plastic bags have a higher efficiency due to a superior surface-to-volume ratio; however, they are not recommended for use because they are not readily available locally, are difficult to handle, and shatter more easily than plastic bottles (Sommer et al., 1997). Transparent polyethylene plastic bags, which are widely available in the area, have been examined and demonstrated to have a very high disinfection efficiency. However, for the same reasons that UNICEF (2005) lists for the SODIS bag, utilizing these bags is not recommended.

2.15 Regrowth of Microorganisms

One of the risks that prevents solar disinfection from being used widely is the potential for bacterial regrowth after inactivation during storage. Depending on the storage water conditions (primarily room temperature), water nutrient content, and level of disinfection achieved (CFU/100 ml), bacterial regrowth may occur, posing a health risk to the final user due to the lack of a residual biocide agent in the disinfected water after SODIS, unlike after sodium hypochlorite disinfection with residual free chlorine (WHO, 1996). Regrowth has been a significant problem for as long as there have been studies on SODIS, starting with Acra et al. (1984). After being kept with a laboratory strain of Escherichia coli in disinfected water for five days at room temperature, the first set of assays revealed no evidence of regrowth. After the first SODIS workshop was held in Montreal (Canada) in 1988, Lawand et al. (1990) compiled the main conclusions and unanswered problems about sun disinfection, including a few that dealt with potential regrowth.

Numerous results were drawn from investigations that used post-irradiation regrowth analyses on SODIS. On the one hand, there are studies that have not found regrowth, such as those by Sommer et al. (1997), who used 30°C as a storage temperature and did not observe any fecal coliform regrowth within 24 h after exposure and complete inactivation, or those by Wegelin et al. (1994), who stored the treated water at 20°C after sun exposure and did not detect any E. coli. According to Mustafa et al. (2013), after being kept at room temperature for a week, 51% of samples in water that had not been thoroughly cleaned began to grow once more. In a more recent investigation, Keogh et al. (2015) used PET bottles and 19-L polycarbonate plastic water cooler containers. After 24 h at room temperature (25°C), there was no regrowth (detection limit of 2 CFU/mL) in the large containers. Nutrient sources in wastewater put the quality of the water at risk since they can influence the chance of microbial regrowth and cause recontamination if the right measures aren't followed (Giannakis et al., 2015). Additionally, new SODIS application results indicate that this technology can be successfully used to regenerate many types of fluids, including wastewater effluents (Gutiérrez-Alfaro et al., 2018). Because viruses can re-grow after being exposed to the sun, SODIS water should be drank within 24 hours (McGuigan et al., 2012).

2.16 Impact of Climate on SODIS

The effectiveness of SODIS and the amount of readily available sunlight are inversely proportional. It is impossible to determine what impacts solar radiation has on Earth as a whole because the strength of solar radiation varies depending on latitude, season, and time of day. A direct correlation exists between the performance of SODIS and the amount of sunshine that is readily available. It is impossible to determine what impacts solar radiation has on Earth as a whole because the strength of solar radiation varies depending on latitude, season, and time of day.

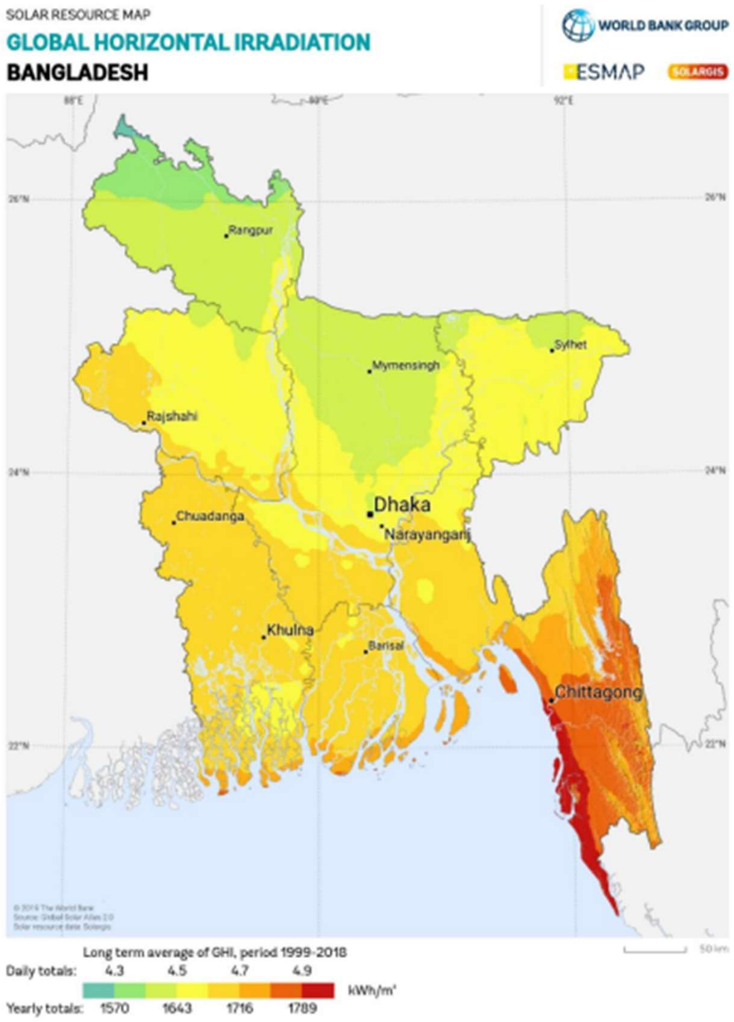


Table 4: Solar Irradiance condition of Bangladesh (world bank, 2020)

2.17 Geography of Solar Radiation

The best latitude range for SODIS is between 15°N and 35°N (and 15°S and 35°S). These semi-arid regions experience the most sun radiation. Most of the poorest nations in the world are located between latitudes 35 degrees north and south. So they can sanitize water for human use using solar radiation. Figure 2.10, which depicts Bangladesh's solar radiation from 1999 to 2018, shows that Bangladesh is located in the ideal SODIS zone.

2.18 Enhancement of SODIS

There are several issues with the "traditional" SODIS technology that need to be fixed. Only very small volumes (two to three liters) can be treated thanks to the use of PET bottles, and the effectiveness of the procedure depends on various factors. Variations in treatment timeframes are a direct result of bacteria's resistance to sunlight's disinfecting powers. Various process enhancements have been looked into to increase the solar disinfection process' effectiveness. These endeavors have included stirring the mixture on a regular basis, adding foil to increase reflectivity, using various containers and additives, sun collectors, and painting the bottom of the bottle black in an effort to increase the temperatures that can be attained.

2.19 Additives

The efficiency of SODIS can be increased by adding additives like titanium dioxide (TiO2) and hydrogen peroxide (H2O2), according to experts (Byrne et al., 2011). Some of these supplements significantly raise the effectiveness of the therapy. But their extensive promotion and implementation in target nations face two significant challenges. The first issue is that the additional chemical makes using the water much more challenging for the consumer without offering any discernible advantages. Even though the amount of time needed to do so is much decreased, exposure for just one or two hours (midday) still poses a practical challenge for people who work outside the home.

2.20 H2O2

The capability of UV radiation to destroy bacteria can be enhanced by advanced oxidation processes (AOPs). Hydroxyl radicals (•OH) are created during these processes. Recent studies have focused on additives that enhance SODIS therapy by generating reactive oxygen species (ROS) like the hydroxyl (•OH) radical, hydrogen peroxide (H_2O_2), superoxide (O^{-2}), and singlet oxygen ($_1O^2$) (Fisher et al., 2008). In solar-powered AOPs, the production of reactive oxygen species, such as •OH radicals, accelerates the inactivation of microorganisms by UVA light. Heterogeneous and homogeneous AOPs are the two forms of AOPs that develop following exposure to light. High quantities of reactive species are necessary for homogenous oxidative reactions (liquid phase reaction) to successfully inactivate microorganisms. The addition of such high levels of oxidants can have a significant negative influence on one's health. They can interact both positively and negatively with bacteria. It is costly to adopt and maintain, and it may result in the production of unfavorable chemical byproducts. Contrarily, heterogeneous oxidative methods (liquid-solid phase reaction) are more effective, inexpensive, eco-friendly, and do not harm helpful microorganisms. Additionally, it is simple to use and effective at inactivating bacteria since the ROS generated during this procedure has potent oxidative characteristics that harm microorganisms' cell membranes, proteins, and DNA. However, due to its efficiency in generating the •OH radical, PhotoFenton has attracted a lot of attention. By mixing hydrogen peroxide with water that has dissolved iron and iron salts, both heterogeneous and homogeneous materials form in the solution.

Both the direct and indirect aggravation of ROS generation by the internal photo-Fenton reaction are attributed to superoxide and H2O2, which are key mediators of the reaction. When light is present or missing, the inner and exterior workings of the bacteria are demonstrated, and it is assessed how the addition of H2O2 can speed up UV-induced bacterial inactivation.

2.21 Prior to light exposure

At pH 0, hydrogen peroxide (H2O2) has a potential of 1.8 volts, while at pH 14, it has a potential of 0.87 volts. Peters and Venkatadri (2009). In biological situations, H2O2 was connected to regulating biofilm growth and disinfection (Venkatadri and Peters, 2009). Catalases and peroxidases control ROS concentrations and keep them at nanomolar levels, while auto-oxidation of bacterial respiratory dehydrogenases creates H2O2 as a natural consequence of respiration (Imlay, 2003). H2O2 is an uncharged molecule that has been observed to diffuse across membranes and enter cells when it is present in the surroundings of microorganisms (Seaver and Imlay, 2001). Imlay and Linn's studies with mm (miliMolar) dosages of H2O2 showed a link between the addition of H2O2 and cell inactivation (Imlay and Linn, 1986, 1988). Concentrations between 1-3 mm H2O2 and >20 mm can be roughly divided into two categories. According to Uhl et al. (2015), internal and external damage was documented in the Mode I and Mode II categories. According to Park et al. (2005), it was demonstrated that M concentrations disrupted cellular catabolic and biosynthetic processes by destroying Fe/S clusters (Jang and Imlay, 2007; Keyer and Imlay, 1996; Liochev and Fridovich, 1994; Touati et al., 1995). Fenton reactions will start if there is too much H2O2, and the shattered cluster aids in the release of free iron. Despite the fact that H2O2 is an oxidant, other oxidants can also scavenge electrons. One-electron transfer is especially used to produce hydroxyl radicals (HO). Mode Even though the methods used may be direct or indirect, there will still be a killing (Imlay and Linn, 1986). The less reactive superoxide anion, which H2O2 can produce by scavenging HO (Imlay and Linn, 1986), has a lower oxidative potential but is still physiologically significant due to its high affinity for bacterial components (Halliwell and Gutteridge, 1984). Furthermore, it is a lot more stable than HO. Intriguing Fenton-related implications arise from the large-scale addition of H2O2 to the bulk under saturated conditions.

2.22 After light exposure

These types of additions are referred to as Mode I killing because extremely small volumes of H2O2 are frequently utilized in research (Garcia-Fernández et al., 2012; Rincón and Pulgarin, 2004; Spuhler et al., 2010). Researchers found no inactivation at doses below 15 mg/l (0.44 mm); at 10 mg/l (0.29 mm), Sciacca et al. noted a 2-log reduction; and at concentrations of 8.5 mg/l (0.25 mm), they only found minor inactivation in the dark (Ndounla et al., 2013; Sciacca et al., 2010). Ananthaswamy and Eisenstark (1976) and Hartman and Eisenstark (1980) reported synergistic inactivation by near-UV radiation and H2O2 for phages and E. coli, respectively. A few instances of the numerous additional works that have been produced to assess the H2O2-enhanced photokilling modes and factors at play are Fisher et al. (2008), Garcia-Fernández et al. (2012), Ng et al. (2015), Sciacca et al. (2010), and Spuhler et al. (2010). When bacteria are treated with hydrogen peroxide, which disinfects them quickly when exposed to solar radiation, the cells are completely destroyed. In order to speed up the death of bacteria in water within the permitted time for disinfection and generate bacterium-free water as a result, SODIS and H2O2 can be used together.

2.23 Benefits of Hydrogen Peroxide in a Wide Range of Applications

There are several benefits to using hydrogen peroxide (H2O2) in the SODIS process to inactivate microorganisms:

Improved disinfection: Strong oxidizer hydrogen peroxide may render many microorganisms, such as bacteria, viruses, and protozoa, inactive. Due to its strong oxidative characteristics, bacteria are rendered inoperable by the breakdown of cellular structures and components.

Accessibility and simplicity: Hydrogen peroxide is used in SODIS in a straightforward manner. It is suitable for resource-constrained locations or emergency scenarios when traditional water treatment technologies might not be available because it does not require complex equipment or a lot of technical knowledge.

Rapid action: Hydrogen peroxide's quick destruction of bacteria encourages prompt disinfection. As solar exposure times are frequently longer and the addition of H2O2 can hasten the inactivation of bacteria, this is especially beneficial for SODIS.

Cost-effectiveness: Hydrogen peroxide is a cost-effective option for microbial inactivation when utilizing SODIS because it is easily accessible and incredibly affordable. Its cost encourages its use in areas with little access to potable water.

Environmental friendliness: Hydrogen peroxide readily decomposes into water and oxygen, leaving no potentially harmful byproducts in the water that has been treated. This makes it an environmentally friendly alternative for disinfecting water because it doesn't add additional chemical contaminants.

Storage stability: Hydrogen peroxide may be maintained properly to maintain its potency for a long time, providing a dependable and stable method of disinfection for SODIS applications. Therefore, when utilizing SODIS to inactivate bacteria, hydrogen peroxide offers a variety of advantages. It is a potent tool for promoting safe and accessible water disinfection, especially in environments with limited resources, because to its improved disinfection capabilities, broad-spectrum activity, simplicity, rapid action, environmental compatibility, cost-effectiveness, and storage stability. In order to inactivate microorganisms, several researchers opt to use H2O2 as a photo catalyst (Sciacca et al., 2010; Rubio et al., 2013; Navarro et al., 2019).

2.24 Health Impact of SODIS

The majority of HWTS projects assess how well the project reduced the prevalence of diarrhea or the risk of infection. Trials evaluating SODIS's health impacts have not consistently shown a decrease in diarrhea (Table 2.7). The great majority of randomized controlled trials have reported decreases in disease incidence of 26-37% (Sobsey et al., 2008). Conroy et al. (1996) conducted one of the earliest SODIS randomized controlled trials (RCTs), and they discovered a 34% reduction in diarrhea and a 35% reduction in severe diarrhea after 12 weeks. The same researchers carried out a follow-up trial a year later and found that the rate of diarrhea cases had dropped by 16%(1999; Conroy et al.). Additionally, the same authors discovered that after SODIS was implemented during an outbreak, the incidence of cholera was reduced by 88% in children under the age of 6 (95% confidence interval (CI): 35%-98% reduction), but the effect was not statistically significant in children aged 6 to 15 years old(Conroy et al., 2001). The buy-in of Massai elders ensured high compliance rates among community members in a number of the earlier SODIS investigations that were conducted in high-compliance settings, such Massai communities (Conroy et al., 1996, 1999, 2001). In a recent experiment with poor compliance, positive but modest reductions in diarrheal sickness were observed (Mäusezahl et al., 2009). Drinking SODIS water has reduced the incidence of water-borne illnesses such dysentery, typhoid, and cholera in various East Asian and sub-Saharan African countries (Conroy et al., 1996, 2001; du Preez et al., 2010). This is mostly due to the ability of solar UV radiation to eradicate harmful germs, including poliovirus and Giardia cysts (Heaselgrave et al., 2006; Quinones et al., 2006). One of the many potential advantages of drinking SODIS water is a boost to human immune system. Water after SODIS may contain a wide variety of microbial antigenic determinants or epitopes, while their precise nature is unclear (Bosshard, Bucheli, et al., 2010; Bosshard et al., 2009). Additionally, more investigation is required to establish the most efficient way to introduce SODIS technology to communities. The assessment of alternative technological techniques to address the inadequacies of conventional SODIS should also be taken into consideration in these efforts. Suggestions that either increase SODIS's output or minimize the stress created by the daily ritual of filling bottles and laying them in the sun should be given priority. The ability of SODIS-inactivated pathogens to produce immunological changes that have protective benefits is linked to the process of microbial inactivation by the sun. The biocidal effect that kills microorganisms during SODIS is caused by sun ultraviolet (UV) radiation (both A and B), or by the interaction of UV and solar heat (Nelson et al., 2018).\

2.25 Positive Aspects of SODIS

One of the key advantages of SODIS is how simple it is to use. In many third-world nations, plastic bottles are inexpensive or even free, according to those who support this technique. It also has the added advantage of being less expensive because no additional chemicals, machinery, or fuel are required.

The main aspect in SODIS's universal acceptability, according to its proponents, is that it does not alter the taste, smell, or look of the water or create any overdose hazards. What follows is an example of the several more advantages that should be stated (Luzi et al., 2016; Meierhofer, 2006), which are provided below.

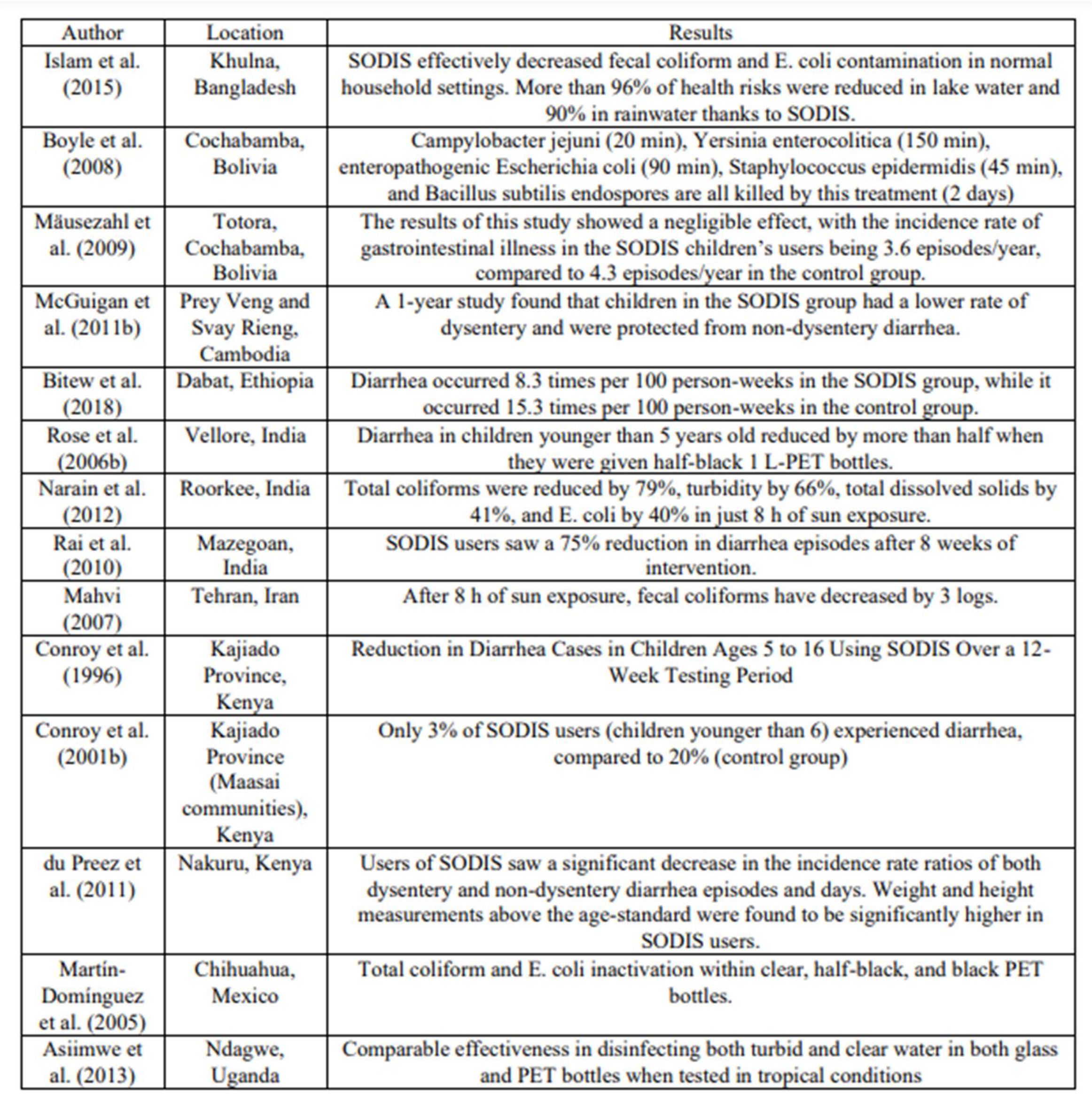
The family's general health improves as a result of the SODIS system. The concept of disinfection of water using SODIS is very simple. In public water supply systems in impoverished nations, water filtration systems are frequently insufficient or nonexistent. Users of SODIS are given an easy-to-use method that they may put into practice at the household level with their own initiative and accountability. The use of SODIS lowers reliance on firewood, kerosene, and other fossil fuels. Deforestation is a significant environmental problem in many developing nations, but by converting to SODIS, the air pollution brought on by burning fossil fuels can be reduced. Because fewer resources will be required for medical treatment when the user's family's health improves, the user can save money. Additionally, the costs of common fuels like gas, kerosene, and firewood are reduced. It won't cost much money to obtain some clear plastic bottles. Due to this, even the most disadvantaged people may afford SODIS. Essential protections against recontamination of water stored in SODIS bottles. The water's taste is unchanged. No reliance on other parties to distribute anything besides PET bottles.

2.26 Drawbacks of SODIS

Potential SODIS limitations that could hinder the technology's general implementation include labor needs, bottle scarcity, and fluctuating disinfection effectiveness—especially in cloudy situations (Fisher et al., 2008; Oates, 2001). Another problem is that users do not stick to the SODIS method as required (Mäusezahl et al., 2009). However, the germicidal effects of the sun are diminished when less sunlight reaches the earth as a result of cloud cover. Despite this restriction, Acra et al. (1984) claim that lengthening the exposure period more than makes up for the reduced sun intensity. Another problem may be finding the materials necessary for solar disinfection. Clear, cylindrical bottles are ideal for solar water purification because they allow more light to enter the container. However, in rural areas where plastic water bottles are less ubiquitous, it may be difficult to get these bottles for general use. For instance, foil is an improvement that many researchers utilize, but purchasing it in bulk can be expensive (Kehoe et al., 2001). For SODIS to operate, enough sunshine is required. As a result, it depends on the climate and weather. SODIS requires access to clean water. SODIS is useless when dealing with big amounts of water and extremely poor effectiveness against several deadly viruses and protozoa. There is no way to guarantee the process' success, and the length of time needed for therapy with SODIS is arbitrary. Due to the overcast weather, efficacy is lower during the monsoon and winter seasons.

2.27 Uses of SODIS in the Field

Around 5 million people use SODIS around the world. In low-income nations, 1.5- to 2-liter PET bottles are frequently used for this purpose since they are affordable and generally available. Researchers in Africa, Latin America, and Southeast Asia have investigated the efficiency of PET bottles for microbial inactivation and their effects on human health in terms of reducing the incidence of diarrhea (McGuigan et al., 2012).



Author	Location	Results
Islam et al. (2015)	Khulna, Bangladesh	SODIS effectively decreased fecal coliform and E. coli contamination in normal household settings. More than 96% of health risks were reduced in lake water and 90% in rainwater thanks to SODIS.
Boyle et al. (2008)	Cochabamba, Bolivia	Campylobacter jejuni (20 min), Yersinia enterocolitica (150 min), enteropathogenic Escherichia coli (90 min), Staphylococcus epidermidis (45 min), and Bacillus subtilis endospores are all killed by this treatment (2 days)
Mäusezahl et al. (2009)	Totora, Cochabamba, Bolivia	The results of this study showed a negligible effect, with the incidence rate of gastrointestinal illness in the SODIS children's users being 3.6 episodes/year, compared to 4.3 episodes/year in the control group.
McGuigan et al. (2011b)	Prey Veng and Svay Rieng, Cambodia	A 1-year study found that children in the SODIS group had a lower rate of dysentery and were protected from non-dysentery diarrhea.
Bitew et al. (2018)	Dabat, Ethiopia	Diarrhea occurred 8.3 times per 100 person-weeks in the SODIS group, while it occurred 15.3 times per 100 person-weeks in the control group.
Rose et al. (2006b)	Vellore, India	Diarrhea in children younger than 5 years old reduced by more than half when they were given half-black 1 L-PET bottles.
Narain et al. (2012)	Roorkee, India	Total coliforms were reduced by 79%, turbidity by 66%, total dissolved solids by 41%, and E. coli by 40% in just 8 h of sun exposure.
Rai et al. (2010)	Mazegoan, India	SODIS users saw a 75% reduction in diarrhea episodes after 8 weeks of intervention.
Mahvi (2007)	Tehran, Iran	After 8 h of sun exposure, fecal coliforms have decreased by 3 logs.
Conroy et al. (1996)	Kajiado Province, Kenya	Reduction in Diarrhea Cases in Children Ages 5 to 16 Using SODIS Over a 12-Week Testing Period
Conroy et al. (2001b)	Kajiado Province (Maasai communities), Kenya	Only 3% of SODIS users (children younger than 6) experienced diarrhea, compared to 20% (control group)
du Preez et al. (2011)	Nakuru, Kenya	Users of SODIS saw a significant decrease in the incidence rate ratios of both dysentery and non-dysentery diarrhea episodes and days. Weight and height measurements above the age-standard were found to be significantly higher in SODIS users.
Martín-Domínguez et al. (2005)	Chihuahua, Mexico	Total coliform and E. coli inactivation within clear, half-black, and black PET bottles.
Asiimwe et al. (2013)	Ndagwe, Uganda	Comparable effectiveness in disinfecting both turbid and clear water in both glass and PET bottles when tested in tropical conditions

Table 5: Recent Findings of SODID Efficiency

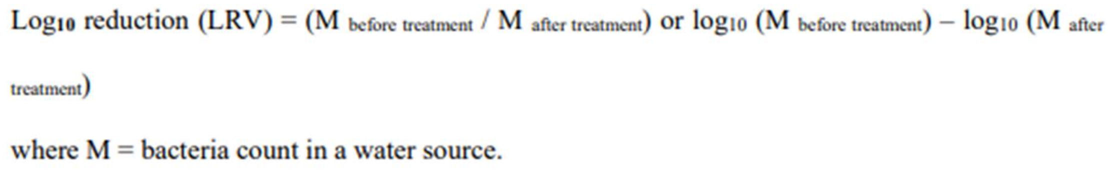
The possibility of increasing exposed surface area and solar radiation has been explored in addition to PET bottles. SODIS bags made of low density, food-grade polyethylene are one of these substitutes. However, the SODIS bags were too large to be employed as a common home treatment even if some of the SODIS bags were shown to have good disinfection efficacy. In the event of a natural disaster, the bags are a practical choice due to their portability, robustness, and low cost (McGuigan et al., 2012). To encourage people to utilize SODIS for water disinfection, more SODIS applications are needed because field application is also limited everywhere.

2.28 Guidelines for Assessing the Effectiveness of HWT Technologies

.Water quality can be lowered for everyone, from the water's source to the ultimate user, at any step in the chain of distribution where pathogenic contamination can happen. Through a mix of measures, pathogenic pollutants must be controlled and infection risk must be reduced. The largest microbiological risk comes from consuming water contaminated with harmful pathogenic bacteria, viruses, protozoa, or helminths. Due to contamination at various stages, some types of water, such as pipe water and other source water, are no longer regarded as safe, leading to an increase in the need for household water treatment (HWT) (WHO, 2019). The WHO has declared that HWT and POU can be used interchangeably. It has been established that a variety of technologies, tools, or techniques, referred to as household water treatment (HWT) or point of use (POU) treatment, can be used to treat water at the household level or at the point of use in other settings, such as schools, hospitals, and other community locations (WHO, 2011).

2.29 Log Reduction Value (LRV)

LRV, often known as log10 reduction, is a measurement of a technology's capacity to eradicate germs. It refers to the capability of eradicating microbes. A simple mathematical tool for evaluating microbe concentration in relation to source water quality is the reduction factor (LRV). The measure of how many times more dead germs were eliminated from a surface following disinfection is known as "logarithmic reduction of microorganisms" (LRV).A simple summary of the LRV computation is provided below:



$$\text{Log}_{10}\text{ reduction (LRV)} = (M_{\text{before treatment}} / M_{\text{after treatment}}) \text{ or } \log_{10} (M_{\text{before treatment}}) - \log_{10} (M_{\text{after treatment}})$$

where M = bacteria count in a water source.

LRV must be used to assess the efficacy of well water treatment technology, according to all applicable regulations and guidelines. Because of this, experimental decisions based on log10 reductions (LRVs) must be used to validate through control measures under a variety of conditions until epidemiological data are collected and/or where epidemiological research may not be feasible or acceptable (WHO, 2011). This can be demonstrated as follows:

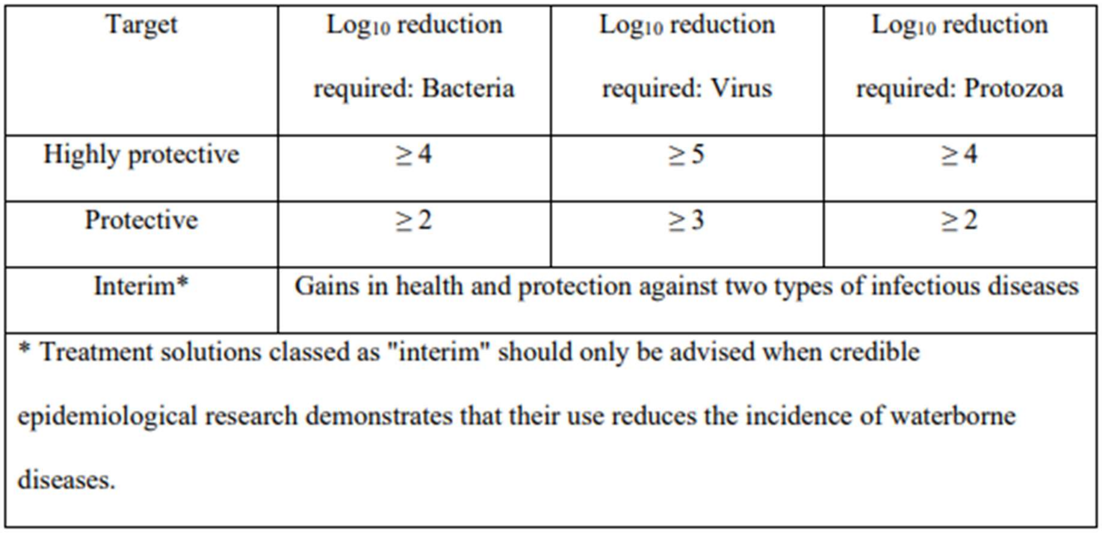
- A 90% reduction corresponds to a 1 LRV, a 95% reduction to a 2 LRV, a 99.9% reduction to a 3 LRV, and so on. A 5-log10 decrease, or 99.999 %, is substantially more stringent than a 2-log10 reduction, or 99 %, requirement.

- Technology would be deemed effective against bacteria if it could decrease their population by 5 log10, or 100,000-fold.
- The amount of dangerous microorganisms in water would decrease by a factor of 5 log10, from 100,000 to 1.

A technology's value can be assessed by how well it prevents the spread of the three most harmful pathogens—bacteria, viruses, and protozoa. This means that any evaluation of an LRV must take into account the number of target organisms that have been eradicated. The physicochemical requirements and briefly discussed microbiological requirements are described in the Environmental Conservation Rule (ECR) of 2023, which also specifies the standards for Bangladesh's drinking water quality. For evaluating such water treatment facilities, however, Bangladeshi standards do not provide a reference point.

2.30 Each Organism's Performance Goal

Table 2.9 displays the recommended performance thresholds for technologies to eradicate bacteria, viruses, and protozoa/spores (WHO, 2011a).



Target	Log_{10} reduction required: Bacteria	Log_{10} reduction required: Virus	Log_{10} reduction required: Protozoa
Highly protective	≥ 4	≥ 5	≥ 4
Protective	≥ 2	≥ 3	≥ 2
Interim*	Gains in health and protection against two types of infectious diseases		
* Treatment solutions classed as "interim" should only be advised when credible epidemiological research demonstrates that their use reduces the incidence of waterborne diseases.			

Table 6 Performance analysis by WHO(WHO,2011)

Highly protective technologies are those that, when used correctly and consistently over the course of a full year, reduce the disease burden related to water consumption to less than 10-6 disability-adjusted life years (DALYs) per person. This is a fairly conservative goal in terms of health, and the use of such technology need to be heavily promoted. A second tier, marketed as "protective," has been built with a higher standard for the permissible degree of disease excess in order to accomplish the same goal of giving high-quality, safer water.

Targets that are both highly protective and protective are conservative; as a result, a "interim" aim has been devised to take into consideration the possibility that achieving both may not be the most practical or affordable course of action. The "interim" target, which is defined as the eradication of two categories of pathogens, is open to technological advancements that have a track record of reducing diarrheal and waterborne infections. In order to progress further toward the ultimate "very protective" goal, achieving this intermediate goal should act as a springboard.

3. Methodology

In this chapter, you will learn about experiments conducted in the IUT Environmental Laboratory for modified SODIS with H2O2, using test waters and drinking water samples collected from various places such as restaurants, slums, and households. The experiments were conducted during the monsoon (June-October) and winter (November-February). Additionally, the chapter outlines the steps for preparing test waters according to WHO standards, procedures for E. coli culture and spiking, physicochemical and bacteriological parameter analysis, bacterial inactivation model, and statistical and regression analysis.

3.1 Preparation of test water:

Karim et al. (2021) describe a procedure for the culture of E.coli. The E.coli was collected from the Environmental Microbiology Laboratory of the International Centre for Diarrheal Disease Research, Bangladesh (ICDDRB) Dhaka. The strain of the sample was subcultured on MacConkey agar. For the differentiation and enumeration of E. coli, modified mTEC agar was utilized in a single-step, single-medium procedure recommended by EPA Method 1603, which was released in 2002. Using an overnight culture of E. coli ATCC 25922 established on mTEC agar, a suspension of E. coli was prepared in normal saline. 100 ml of diluted solution was cultivated using a drop plate technique. It was determined that the E. coli was in the range of 107 CFU/100 ml. Before spiking, the saline was placed in a water bath to bring its temperature down from its storage temperature of approximately -15°C to room temperature

3.2 PET Bottles and Plastic Bags:

Aquafina and Kinley water bottles (500 ml capacity) were purchased from the local market and IUT canteen. Plastic polymer bags were purchased from shops . All labels were removed from the bottles to provide sufficient surface for the UV-visible light transmission. The bottles and Bags were sterilized to provide a suitable bacteria-free test environment. When the containers showed suitability in passing adequate UV radiation, they were selected.

3.3 Test Water

The WHO suggested using two test waters to test a variety of possible untreated water sources for the laboratory verification of HWT technologies. The present study followed these guidelines.

Focus	TestWater-1	TestWater-2	Reference
Description	Groundwater	Groundwater + Autoclaved Drain water (1% of Volume)	WHO
Turbidity	<5 NTU	> 30 NTU	WHO
pH	7.0-9.0	6.0-10.0	WHO

To prepare the test water, two 10-liter water containers were cleaned and sterilized. Then, 10 L containers were filled with groundwater used in the IUT water supply. The following methods were used to prepare the test water samples

Test water 1:

The IUT groundwater provided test water 1: TW-1 turbidity 5 NTU and a pH range of 7.0-9.0.

The water was then put into six PET bottles and six plastic bags, which were laced with 107 CFU/100 ml of E. coli two hours before the SODIS experiment.

Test water 2:

The same groundwater was sterilized in an autoclave at 121°C for 24 hours after being combined with 1% by volume of sewage water obtained from the IUT sewer line. TW-2 required turbidity greater than 30 NTU, which was accomplished by adding clay that had been processed through a 200 mm screen. This clay was extracted from an undisturbed soil sample 30 m beneath the ground surface. The material from the Chittagong roadway was investigated at the Geotechnical Laboratory. This material was passed through a 200-mm sieve to get clay. The water had a turbidity of more than 30 NTU and a pH of 6.0 to 10.0. TW-2 was placed into six PET bottles and six plastic bags two hours before each SODIS experiment and spiked with 107 CFU/100 ml of E. coli bacteria.

Reactors in batches:

As reflecting reactors, reflective food-grade foil sheets were added to the rear surfaces of PET bottles and plastic bags.

H2O2:

According to the United States. The Environmental Protection Agency (EPA) recommends a minimum dosage of H2O2 in drinking water of 25-50 mg/l. Furthermore, Sciacca et al. (2010) discovered that 10 mg/l H2O2.The germs were highly inactivated when exposed to sunlight. According to the literature, 10 mg/l of 30% EMSURE ® ISO H2O2 was added to each PET bottle PB one hour before the SODIS experiment. Before each experiment, an E. coli test was done to ascertain the starting bacterial count before solar exposure to examine the influence of H2O2 as an oxidizing agent on bacterial inactivation.

3.4 Experimental Procedure:

After that, both sets of PET bottles and PB were put on the prototype system and subjected to sunshine. The SODIS trials were all carried out on the IUT campus. Before solar exposure, reactors (PET bottle and PB) were shaken to maintain an air gap of approximately 15% of the container volume to allow for air circulation and aeration (Reed, 1997). Containers were placed out in the sun for 6 hours, commencing at 10 a.m. (+/- thirty minutes) and ending at 4 p.m. (+/- thirty minutes) in all cases.

Throughout the studies, the Solar Survey 200R Pyranometer (Seward Group, UK) was used to record the sun's irradiance and temperature at 1-minute intervals. Six TW-1 containers and six TW-2 containers were exposed at the same time for a total of 12 containers in each experiment. During the monsoon and winter months, six-hour exposure tests were conducted, with each sample water container being retrieved from the sun irradiation exposure chamber for testing every h. During the monsoon and winter, all trials were repeated in duplicate for each condition.

3.5 E.coli Testing:

During the monsoon and winter seasons, samples were gathered from the SODIS platform after each hour of sun exposure. To guarantee sterility, the samples were kept in sterile beakers. Six PET bottles and six PB from TW-1 and TW-2 were sampled for E. coli testing in each trial.

After SODIS, the water was put in a dark setting for 12 and 24 hours at room temperature to see if the microbes regrew (Giannakis et al., 2015). Each sample received 100 ml of 0.22-micron-pore filter paper (Millipore Corp., Bedford, MA, USA). Following the membrane filtering procedure (APHA 1998), the filter paper was put in a broth containing m-TEC agar in a glass Petri plate. The samples were incubated for 24 hours at 37°C. The characteristic white-grey appearance of E. coli colonies allows for a visual count of the total number of colonies. The total number of E. coli colonies in each sample was counted after incubation. E. coli tally was represented as CFU/100 ml, and all assays were repeated twice to ensure accuracy. The mean of the two tests was then calculated.

3.4 Physical and Chemical Testing

During the SODIS tests, four physicochemical parameters were measured: pH, turbidity, dissolved oxygen (DO), iron (Fe), and electrical conductivity (EC). These characteristics were determined for both test and filtered water.

3.5 SODIS Experiments with Drinking Water from Slums, Restaurants, and Households

The drinking water utilized in various facilities (households, restaurants, and slums) was gathered from several locations across Dhaka, as illustrated in Fig. 3.10, and the locations are shown in Table 3.5. Piped water from the Dhaka Water Supply and Sewerage Authority (DWASA), jar water from private companies and tube wells, and hand-pumped groundwater are the principal sources of drinking water in Dhaka.

Table 7: Drinking Water Sampling Locations

Establishment Type	**Location**	**Location**	
		Latitude (Decimal Degrees)	**Longitude (Decimal Degrees)**
Slum	Mirpur	23.829929	90.377347
Slum	Mirpur	23.829591	90.377390
Slum	Mirpur	23.829969	90.377279
Slum	Mirpur	23.827956	90.378214
Restaurant	Mirpur	23.829920	90.376566
Restaurant	Mirpur	23.829181	90.375344
Restaurant	Mirpur	23.829756	90.375376
Restaurant	Uttara	23.87986	90.401
Household	Mirpur	23.831455	90.374773
Household	Malibagh	23.756879	90.415067
Household	Uttara	23.863760	90.403168
Household	Bashundhara	23.812926	90.452894

Table 8:Locations of water sources for sampling

Various establishments were chosen at random from various places to gather drinking water samples. The drinking water was collected in PET bottles (2-L) and placed in a cotton bag to avoid exposure to sunlight. Water samples were transferred by air the same day they were collected. Conditioned automobile to the laboratory. SODIS studies were carried out using collected drinking water samples with and without H2O2 during 6 hours of sun exposure to assess treatment efficiency. During the winter, reactors (PET and PB) were employed under overcast weather conditions. The H2O2 dose was 10 mg/l.

The physicochemical and E. coli tests were carried out in the same manner as the test water experiment. In addition, all trials included a post-SODIS regrowth examination of bacteria.

3.6 Water quality of the Drinking Water Samples

The drinking water samples were analyzed for various physicochemical and bacteriological parameters before the SODIS experiment. Table 3.6 shows the results of the water quality of the collected drinking water samples before the SODIS experiment. In each sample, drinking water was labeled with an ID, such as R 1–4 for restaurants, S 1–4 for slums, and H 1–4 for households.

Type	Location	Source	Test waters	pH	DO	EC	Temperature of water	Turbidity	Fe	Initial	E.coli 1hr	E.coli 2hr	E.coli 3hr	Regrowth 24	Solar irradiance	Temperature panel
slum	Mirpur	Piped	S-1	8.49	2.99	378	38.5	6.25	0.82	721	423	98	0	0	550.373961	45.45152355
slum	Mirpur	piped	S-2	8.4	4.88	367	38.1	5.48	0.56	634	321	78	0	0	550.373961	45.45152355
slum	Mirpur	tubewell	S-3	8.3	3.12	357	38.2	3.26	0.24	1890	670	200	0	0	550.373961	45.45152355
slum	Mirpur	piped	S-4	8.3	6.34	326	38.5	0.35	0.15	1520	532	178	0	0	550.373961	45.45152355
Household	Mirpur	piped	H-1	8.36	6.81	398	38.4	3.02	0.64	840	301	34	0	0	550.373961	45.45152355
Household	Malibagh	piped	H-2	8.24	6.7	406	38.5	0.16	0.45	540	299	21	0	0	550.373961	45.45152355
Household	Uttara sector 4	piped	H-3	8.33	6.76	329	38	0.35	0.29	470	289	19	0	0	550.373961	45.45152355
Household	Bashundhora	piped	H-4	8.28	7.24	399	38.1	0.22	0.13	890	276	20	0	0	550.373961	45.45152355
restaurants	Mirpur	Filter (Industrial supply water)	R-1	8.41	7.35	347	37.5	1.61	0.18	500	100	21	0	0	503.643154	40.07883817
restaurants	Mirpur	piped	R-2	8.45	6.92	340	37.1	3.02	0.22	3000	1231	169	0	0	503.643154	40.07883817
restaurants	Mirpur	Drum	R-3	8.39	5.23	343	37.2	3	0.2	980	215	45	0	0	503.643154	40.07883817
restaurants	Uttara	piped	R-4	8.4	7.34	270	37.5	2.38	0.11	1980	321	78	0	0	503.643154	40.07883817

Table 9: Analysis of collected drinking water quality parameters

The majority of the water's physicochemical properties were within the ECR (2023) and WHO (2022b) drinking water criteria. The iron test findings of the drinking water samples were within 0.3-1.0 mg/l of the ECR (2023) norm. The water is unsafe to drink since it contains high levels of E. coli. The risk levels for E. coli are classed as low (1 CFU/100 ml), moderate (1-10 CFU/100 ml), high (11-100 CFU/100 ml), and extremely high (>100 CFU/100 ml) based on existing literature. According to the risk categories, the obtained drinking water samples provide an extremely high danger to human health since E. coli concentrations exceeded 100 CFU/100ml. UNICEF reported similar findings, finding that 32% of piped,

E. coli danger levels were found in 30.4% of tube well water (Charles et al, 2021). Under these conditions, SODIS may be utilized to improve human health by lowering the risk of water-related diseases, and it can also be used as an HWT alternative to disinfecting water before consumption. Analysis of the drinking water quality parameters revealed that the state of the water supplied to the mass population is contaminated and may pose a significant threat to the overall health of the human population.

3.7 Bacterial Inactivation and Simulation

The sun irradiation-induced bacterial inactivation was computed using the GInaFiT freeware add-on in Microsoft Excel (Geeraerd et al., 2005) and LRV. The Weibull frequency distribution model (Mafart et al., 2002) and the bacterial decay model (Chapra, 2008) were chosen because they gave the best-fitting curves in all situations studied. To choose the optimal model, the shortest root-mean-squared error (RMSE) and greatest correlation coefficient (R2) were used.

3.8 Weibull Inactivation Model

To estimate the bacterial reaction to sun irradiation, the GInaFiT freeware add-on in Microsoft Excel was utilized (Geeraerd et al., 2005). The curves from the Weibull frequency distribution model (Mafart et al., 2002) were chosen because they had the greatest R 2 and lowest RMSE of all the models tested.

$$N/N_0 = 10^{-(t/\delta)^{p}}$$

N_0 = The initial bacterial population (CFU/ml)

N_{res} = Residual Bacterial Population (CFU/ml)

k= Inactivation constant in a first-order reaction

t= The investigated time

δ and p= Weibull model-specific constraints

The scale's parameter δ indicates when the reading is rounded down to the nearest decimal place.

For p <1, a convex curve is illustrated. Last but not least, the model structure dictates that d and p are not unrelated to one another; rather, they exhibit a high link, as proposed by van Boekel (2002); Geeraerd et al. (2005), and Mafart et al. (2002). Moreover, according to Raes et al. (2012), model fitting can be considered poor if NRMSLE >30%, fair if 30%>NRMSLE>20%, good if 20%>NRMSLE>10%, and excellent if NRMSLE <10%.

3.8 Statistical Evaluation

Microsoft Excel® ver. 16.1 (Microsoft Corporation, Redmond, WA, USA) and R Studio (R Coding) were used to compare the microbiological analysis and efficacy of various materials. To establish the significance of the dataset, a paired t-test was done on pairs of datasets made up of aluminum foil paper, corrugated steel sheets, PET bottles, or plastic bags.

In addition, analysis of variance (ANOVA) was used to examine each sample for seasonal variations. The significance level for hypothesis testing was set at 5%, and all tests were considered significant if their p-values were less than 0.05 (Clark, 1974).

Furthermore, Equation below specifies the safe exposure period' required to achieve the necessary degree of bacterial inactivation to be maintained throughout SODIS application to minimize microorganism re-growth.

$$tsafe\ exposure = tmodel + 0.2\ tmodel + 30$$

4. Results and Discussions:

For the test water studies in this section, the WHO guidelines for HWT procedures were followed. Experiments were carried out in Bangladesh throughout two gloomy seasons (monsoon and winter) to assess the SODIS's performance. To increase SODIS effectiveness across a wide range of sun exposure periods and circumstances, including overcast days, a prototype SODIS system was built utilizing foil paper. Polyethylene terephthalate (PET) bottles and plastic bags were utilized as reactors in the studies. A consistent technique was used to assess solar irradiance and many physicochemical parameters. The results of many experimental tests are discussed here.

4.1 Physical and chemical properties

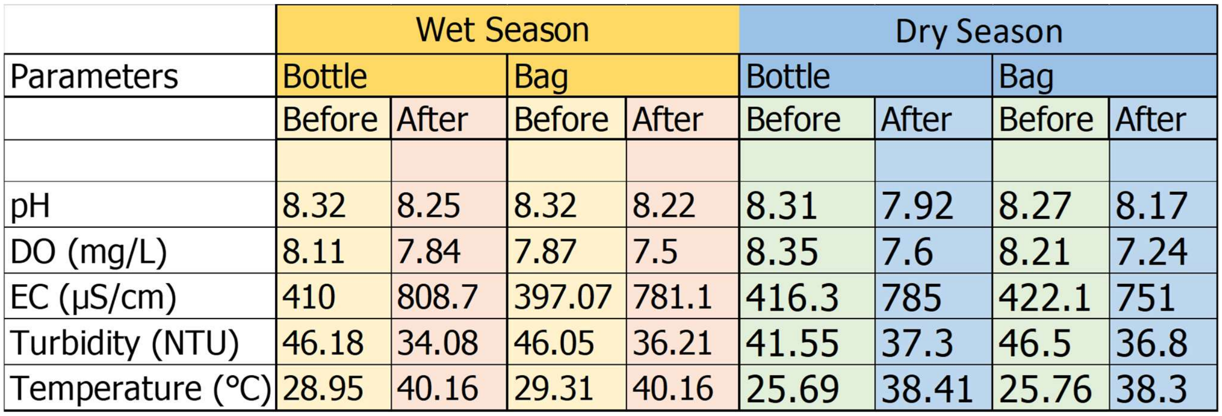
The physicochemical parameters were compared before and after SODIS with H2O2 application. The pH, DO, turbidity, EC, and temperature of the test water were determined in Bangladesh throughout the monsoon and winter seasons. During these seasons, the iron content in IUT groundwater ranged between 0.3 and 0.7 mg/l. Test waters generated in compliance with WHO (2011) recommendations provide optimum (TW-1) and worst-case (TW-2) conditions for comparing different HWT efficiencies fast. The mineral concentration and low organic content of the water used in TW-1 preparation are noteworthy characteristics. Furthermore, TW-2 containing sewage water contained colloidal and organic components that caused physicochemical alterations. Tables A3, A5, A7, and A9 in Appendix II show the average TW-1 (PET bottle and PB) and TW-2 (PET bottle and PB) values obtained using pre-SODIS evaluated parameters for the monsoon and winter seasons. The statistics indicated that there was a seasonal change in water temperature, and all other values were comparable with WHO (2011) guidelines. This study's findings are congruent with those of another study by Clarizia et al. (2017), which discovered that iron in water causes a pH increase to 8.04, mostly due to water oxidation. Appendix II (Tables A4, A6, A8, and A10) presents the post-SODIS parameters based on the average SODIS data over 6 hours. Solar exposure caused temperature fluctuations, while the presence of iron in the water caused an increase in EC. Lowering the pH of water, according to the literature, entails combining the photocatalyst, and enables iron to react with hydrogen ions in water. It was also determined that the cause of the lower DO level may be attributed to the photocatalyst's chemical interaction with iron or other organic material in the water, or to the inactivation of bacteria. The turbidity of TW-2 reduced following the SODIS experiment, as reported by Karim et al. (2021).

This might be attributed to the photocatalyst's chemical interaction with iron or other organic material in the water, or to the deactivation of microbes. The turbidity of TW-2 reduced following the SODIS experiment, as reported by Karim et al. (2021).

4.2 Comparison of SODIS PET bottle and plastic bag test waters before and after SODIS

Table 4.1 shows a comparison of the physicochemical parameters for two types of test waters using PET bottles and plastic bags during the monsoon and winter seasons, allowing the average value of several physicochemical characteristics to be analyzed quickly and easily before and after the application of SODIS with H2O2. The EC value and turbidity of both test waters rose after using the SODIS during the monsoon and winter seasons. The physicochemical properties of both containers changed with temperature; however, neither DO nor pH were modified. The most variable characteristics in both test waters (TW-1 and TW-2) were EC, temperature, and turbidity. The temperature has risen.

The dissociation of molecules in water enhances the mobility of ions, resulting in an increase in conductivity (Barron and Ashton, 2005). Furthermore, conductivity can be improved in this study due to the presence of iron ions as a result of the interaction of H2O2 and iron in water caused by sunshine (Mathur, 2015). Thus, the rise in EC seen in this study was caused by an increase in temperature as well as the presence of Fe ions in the water. Furthermore, pH and DO showed the least fluctuation in both test waters during the monsoon and winter seasons. Karim et al. (2021) observed similar findings.

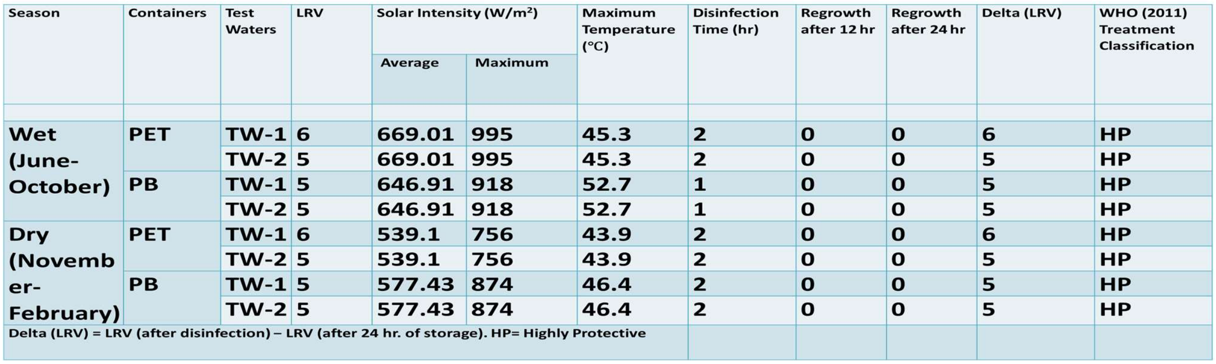


	Wet Season				Dry Season			
Parameters	Bottle		Bag		Bottle		Bag	
	Before	After	Before	After	Before	After	Before	After
pH	8.32	8.25	8.32	8.22	8.31	7.92	8.27	8.17
DO (mg/L)	8.11	7.84	7.87	7.5	8.35	7.6	8.21	7.24
EC (µS/cm)	410	808.7	397.07	781.1	416.3	785	422.1	751
Turbidity (NTU)	46.18	34.08	46.05	36.21	41.55	37.3	46.5	36.8
Temperature (°C)	28.95	40.16	29.31	40.16	25.69	38.41	25.76	38.3

Table 10: Comparison of Parameters Pre and Post SODIS

4. 3 Regrowth of Microorganisms

Microbial regrowth can be caused by a variety of factors, some of which are covered in the literature review sections. Regrowth is a worry from the start of SODIS and continues after treatment is completed. According to Table 4.3, modified SODIS with H2O2 is efficient in suppressing bacterial regrowth, as demonstrated in this investigation. Regrowth after SODIS-treated water, as demonstrated by Karim et al. (2021)'s study in Bangladesh, is a severe issue. People with waterborne diseases will not benefit from SODIS if bacteria in the water regeneration occur after SODIS. As a result, controlling bacterial regrowth in SODIS-treated water is a considerable problem. Both Giannakis et al. (2015) and GutiérrezAlfaro et al. (2018) have published their findings that regrowth is a major finding in the process



Season	Containers	Test Waters	LRV	Solar Intensity (W/m²)		Maximum Temperature (°C)	Disinfection Time (hr)	Regrowth after 12 hr	Regrowth after 24 hr	Delta (LRV)	WHO (2011) Treatment Classification
				Average	Maximum						
Wet (June-October)	PET	TW-1	6	669.01	995	45.3	2	0	0	6	HP
		TW-2	5	669.01	995	45.3	2	0	0	5	HP
	PB	TW-1	5	646.91	918	52.7	1	0	0	5	HP
		TW-2	5	646.91	918	52.7	1	0	0	5	HP
Dry (November-February)	PET	TW-1	6	539.1	756	43.9	2	0	0	6	HP
		TW-2	5	539.1	756	43.9	2	0	0	5	HP
	PB	TW-1	5	577.43	874	46.4	2	0	0	5	HP
		TW-2	5	577.43	874	46.4	2	0	0	5	HP

Delta (LRV) = LRV (after disinfection) – LRV (after 24 hr. of storage). HP= Highly Protective

Table 11:Regrowth Potential of Modified SODIS

4.4 Model of Weibull Inactivation and log-linear+tail model:

The Weibull bacterial inactivation model was utilized by several writers, including Giannakis et al. (2015), Castro-Alférez et al. (2018), and Karim et al. (2021). This model can readily show the efficacy of the SODIS system, the time necessary for disinfection, and the 4-LRV of the SODIS experiment. As demonstrated in Figs. 4.13 and 4.14, the model matches the experimental data using both the plastic bag and the PET bottle during the winter and monsoon seasons. The results show that the data from this investigation fit the Weibull inactivation model rather well.

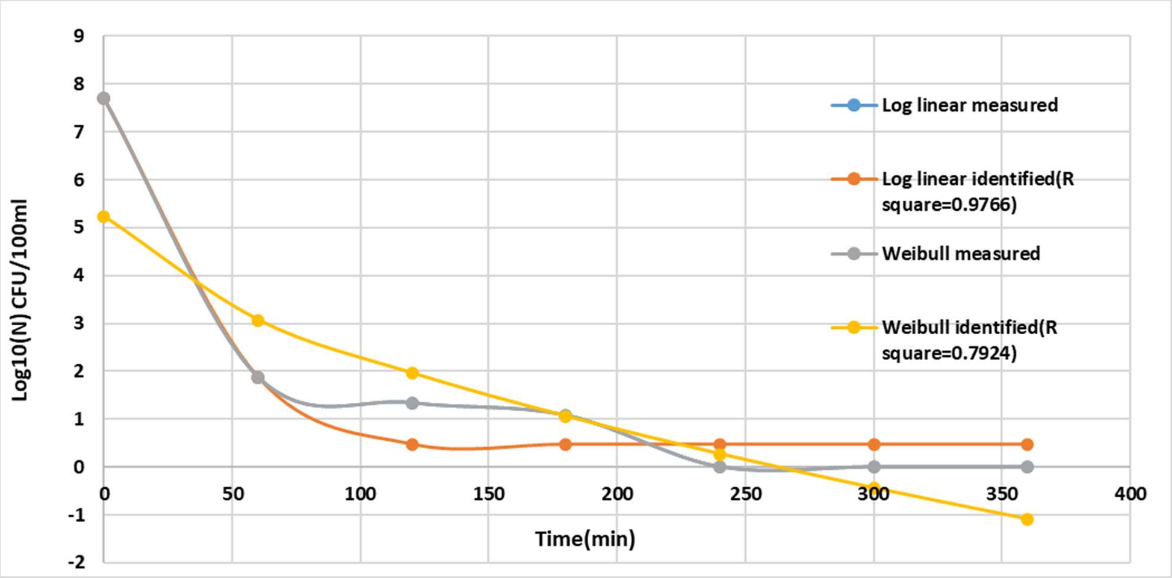


Table12: Comparison of Weibull and Log Linear models

Furthermore, the evaluations provided by Raes et al. (2012) reveal that the model fits are excellent, with NRMSLE values of 10% in all trials done throughout the winter and monsoon seasons. The 4-log exposure length was less than 1 h across all seasons, suggesting that the established SODIS prototype with H2O2 was more effective. Furthermore, Castro-Alférez et al. (2018) established a safe exposure period to prevent microbe regrowth in photo treated water; the safe exposure time in the monsoon and winter seasons is less than 3 h, which is more effective than any previous study done in Bangladesh. Solar exposure averages 646.91 W/m2 during the monsoon season, peaking at 918 W/m2. In contrast, during the winter, the average sun exposure exceeded 450 W/m2, while the maximum temperature exposure exceeded 600 W/m2. The modified SODIS with H2O2 is classified as a highly protective technology that anyone in Bangladesh can readily use to safely consume drinking water.

4.5 Analysis of Regression

In this part, figures from the monsoon and winter seasons were combined, and evaluations were done for both PET bottles and plastic bags (TW-1 and TW-2). The four dependent variables (UV) used in this regression study are maximum water temperature (Tmax), turbidity (Turb), dissolved oxygen (DO), and ultraviolet radiation (UV). The regression model was evaluated using four, three, two, and one dependent variables per container and test water. For each experiment, the coefficient of determination (R 2), standard error (S. E.), and corrected R 2 were computed. The p-value of 0.05 is used as the statistical significance criterion in both significant hypothesis tests.

PB TW-1					
Dependent Variables	Model	R	R^2	R^2adj	S. E
Tmax, Turb, DO, and UV	k= -1.64+0.05Tmax-.37 Turb+0.25 DO +0.002UV	0.80	**0.79**	0.75	0.45
Tmax, Turb and DO	k= -3.71+0.10 Tmax-0.37 Turb+0.46 DO	0.68	**0.68**	0.64	0.50
Tmax and Turb	k= -1.17+0.12 Tmax-0.36 Turb	0.29	0.38	0.13	0.60
Tmax	k= -1.82+0.11Tmax	0.56	0.32	0.30	0.65
Turb	k= 3.74-0.31Turb	0.31	0.10	0.10	0.75
DO	k= -4.77+1.08DO	0.40	0.20	0.20	0.70
UV	k= 0.89+0.004UV	0.70	**0.53**	0.50	0.60
PB TW-2					
Dependent Variables	Model	R	R^2	R^2adj	S. E
Tmax, Turb, DO, and UV	k= -0.46+0.05Tmax-0.01 Turb-0.04 DO +0.003UV	0.70	**0.78**	0.72	0.60
Tmax, Turb and DO	k= -1.86+0.10 Tmax-0.01 Turb+0.05 DO	0.53	**0.58**	0.50	0.65
Tmax and Turb	k= -1.55 +0.11 Tmax-0.01 Turb	0.53	0.35	0.30	0.70
Tmax	k= -1.88+0.1Tmax	0.52	0.30	0.30	0.70
Turb	k= 2.73-0.003Turb	0.03	0.01	0.01	0.80
DO	k= -2.74+0.71DO	0.30	0.10	0.10	0.80
UV	k= 0.57+0.004UV	0.70	**0.56**	0.51	0.60

Table 13: Regression Analysis of PET Bottles and Plastic Bags in moonsoon and winter season

PET TW-1					
Dependent Variables	Model	R	R^2	R^{2}adj	S. E
Tmax, Turb, DO, and UV	k= 1.94-0.05Tmax-.01 Turb+0.19 DO +0.003UV	0.71	**0.70**	0.65	0.40
Tmax, Turb and DO	k= 0.24+0.01 Tmax-0.002 Turb+0.26 DO	0.58	0.45	0.42	0.50
Tmax and Turb	k= 1.68 +0.02 Tmax+0.01 Turb	0.26	0.30	0.09	0.50
Tmax	k= 1.68+0.02Tmax	0.21	0.04	0.01	0.50
Turb	k= 2.60+0.06Turb	0.09	0.00	0.00	0.50
DO	k= 0.36+0.33DO	0.26	0.07	0.03	0.50
UV	k=1.63+0.002UV	0.54	0.35	0.30	0.45
PET TW-2					
Dependent Variables	Model	R	R^2	R^{2}adj	S. E
Tmax, Turb, DO, and UV	k= 1.27-0.03Tmax+.01 Turb+0.02 DO +0.003UV	0.70	**0.73**	0.70	0.40
Tmax, Turb and DO	k= -0.68+0.04 Tmax+0.02 Turb+0.11 DO	0.44	**0.50**	0.45	0.40
Tmax and Turb	k= 0.04 +0.04 Tmax+0.02 Turb	0.43	0.20	0.12	0.50
Tmax	k= 0.50+0.04Tmax	0.40	0.14	0.12	0.50
Turb	k= 1.73-0.02Turb	0.25	0.06	0.02	0.50
DO	k= 1.20+0.16DO	0.14	0.02	0.01	0.50
UV	k=1.05+0.003UV	0.65	**0.55**	0.50	0.40

The models show that the disinfection rate in PET bottles and plastic bags (TW-1 and TW-2) is related to the temperature of the water, the amount of dissolved oxygen, and the amount of UV light. Furthermore, the rate of disinfection was inversely linked to water turbidity. The regression analysis revealed that as the turbidity of the water grew, so did the SODIS disinfection rate. In contrast, increasing the water temperature, dissolved oxygen, and UV radiation will boost the disinfection rate. Several research, including McGuigan et al. (2012), Marugán et al. (2020), Amirsoleimani et al. (2021), and Karim et al. (2021), have proven the similar occurrence in the increase and decrease of the SODIS disinfection rate. Figs. 4,5,6,7 respectively which show significant fittings of the regression model for PET bottles and plastic bags (TW-1 and TW-2) during the monsoon and winter seasons.

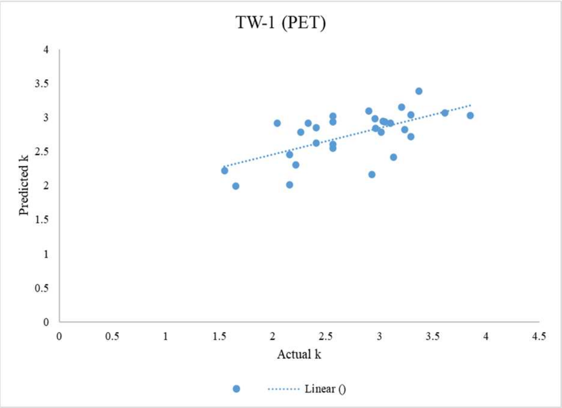


Fig. 4

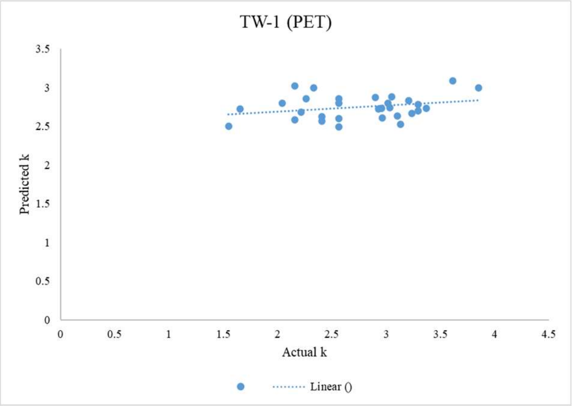


Fig.5

Figure 1:Model fillting of TW-2 (PET) with Tmax, Turb,Do and UV

Figure 2: Model fitting TW-1(PET) with Tmax, Turb,DO,UV

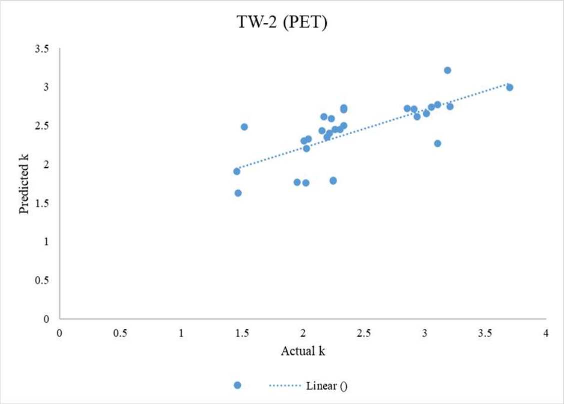


Fig:6

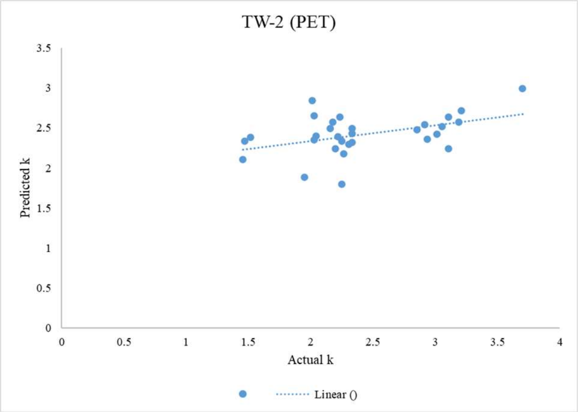


Fig:7

Figure 3: Model fitting of TW_2 with Tmax,Turb,DO and UV as predictors

Figure 4: Model fitting of Tw-2(PET) with Tmax, Turb,Do as predictors

4.6 Cost Analysis:

	Full Setting	**Houses with Corrugated Tin Sheet**	**Unit Cost (BDT)**	**Amount**	**Full Setting Total Cost**	**Houses with Corrugated Tin Sheet Total Cost**
Aluminum Foil	✓	✓	**250**	**1 Roll**	**250**	**250**
Insulation Sheet	✓	−	**100**	**1 Sheet**	**100**	**-**
PET Bottle	✓	✓	**30**	**6 Liter**	**180**	**180**
Corrugated Tin Sheet	✓	−	**200**	**1 Sheet**	**200**	**-**
Wooden Board	✓	−	**650**	**1 Board**	**650**	**-**
Black Enamel Paint	✓	✓	**150**	**1 Paint**	**150**	**150**
H_2O_2	✓	✓	**2000**	**1 Liter**	**2000**	**2000**
Total					**3530**	**2580**

The overall cost of developing the prototype system utilized in this study is shown in Table 4.14, with the only recurrent expenditures being those for aluminum foil paper, PET bottles, and hydrogen peroxide, while the rest components are acquired just once. Any low-income household may do this for a one-time cost of just 3,530 BDT (about $35.3).

4.7 SODIS Performance in Experiments Using Collected Drinking Water Samples

In this part, the SODIS performance was tested utilizing drinking water quality samples obtained from restaurants, families, and slums studies using SODIS. The drinking water samples' quality was assessed, and post-SODIS analysis was done.

This section also examines the differences and similarities between SODIS and SODIS mixed with H2O2.

4.8 Physicochemical Change

When SODIS with H2O2 was utilized, there were no variations in the physicochemical characteristics of the treatment process between the studies done in the test waters and those performed on the collected drinking water samples. The physicochemical parameter changes in SODIS with H2O2 and SODIS are presented in Appendix III (Tables A13 and A14). The parameter changes followed a similar pattern to what was found in the test waters. Because all of the drinking water sources include iron, the photo-Fenton process will occur by the addition of H2O2 in SODIS, which will accelerate the inactivation of bacteria identical to the test waters.

4.9: Efficiency of SODIS with H2O2:

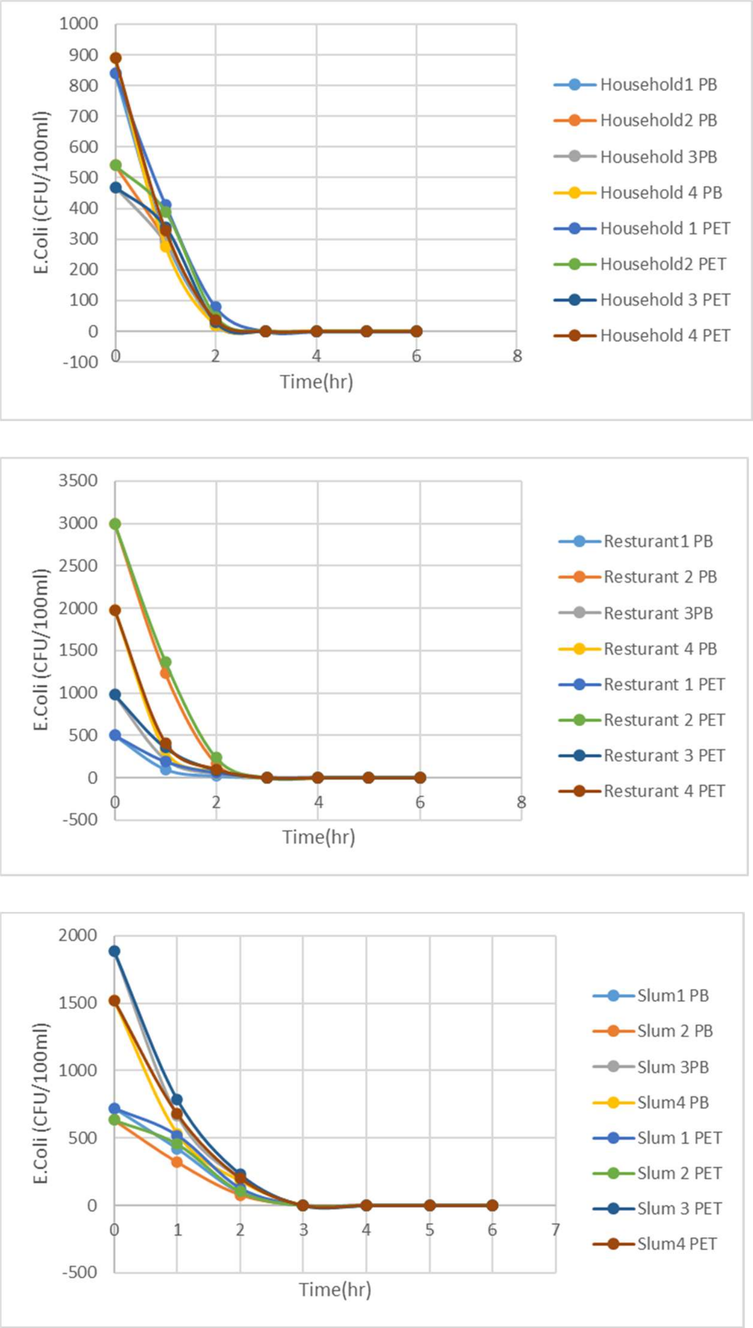


Figure 5: Efficacy of SODIS in Collected drinking water

Fig. 4.24 depicts the efficacy of SODIS with H2O2 in a PET bottle. SODIS with H2O2 takes 2 hours to completely inactivate microorganisms, and this efficiency has been found in a range of drinking water samples. Furthermore, SODIS studies in plastic bags were more efficient than those in PET bottles. The figures show that combining SODIS with H2O2 increases the performance of SODIS alone and has the potential to be used in the field. Outside of the winter months, no fieldwork was done, and vice versa. SODIS treated with hydrogen peroxide is more effective in the summer, when temperatures are greater, and bacterial inactivation can be noticed after just 1 hour.

4.10 Regrowth Potential:

Furthermore, several studies have explored the regeneration of bacteria, which severely hampers SODIS. The findings of this investigation show that in the winter, SODIS treatment alone cannot inhibit bacterial regrowth following SODIS application and comparable results were achieved in the winter season by Karim et al. (2021). Furthermore, Karim et al. (2021) found that it took more than 6 hours to fully inactivate the bacteria and that regrowth occurred following SODIS administration. Reyneke et al. (2020) did an experiment using rainwater in South Africa and Uganda and discovered bacterial proliferation after 8 hours of sunlight exposure in sunny weather conditions using acrylic glass tubes. SODIS was used to stream water in research in Brazil by placing PET. After 25 hours of solar exposure in gloomy conditions, bacteria regrew in bottles in zinc corrugated tin sheets (Rosa e Silva et al., 2022). Martnez-Garca et al. (2021) discovered bacterial proliferation in transparent tubes after 5 hours of sunlight exposure in sunny weather conditions using isotonic and demineralized water spiked with E. coli. SODIS usage may be hazardous to human health, according to studies undertaken in several countries, including Bangladesh. Thus, the findings of this study suggest that combining SODIS with H2O2 may suppress bacterial regrowth after treatment and offer potable water after storage, which may convince consumers to accept SODIS as a viable HWT alternative for killing germs.

Type	**Location**	**Source**	**Test Waters**	**Temperature (℃)**	**Turbidity (NTU)**	**DO (mg/l)**	**pH**	**EC (µS/cm)**	**E.coli (CFU/100ml)**	**Fe (mg/l)**
Restaurants	Mirpur	Jar Water	R-1	22.8	0.63	8.06	7.67	297	500	0.82
Restaurants	Mirpur	Piped	R-2	22.3	1.64	7.59	7.42	286	3000	0.56
Restaurants	Mirpur	Drum	R-3	22.3	1.33	6.22	7.8	294	980	0.24
Restaurants	Uttara	Piped	R-4	22.4	1.25	8.29	7.36	209	1980	0.15
Slum	Mirpur	Piped	S-1	25.5	7.53	3.56	7.38	296	721	0.64
Slum	Mirpur	Piped	S-2	25.6	6.25	5.45	7.22	297	634	0.45
Slum	Mirpur	Tubewell	S-3	25.6	3.42	3.31	7.12	297	1890	0.29
Slum	Mirpur	Piped	S-4	24.6	0.45	6.78	7.28	222	1520	0.13
Household	Mirpur	Piped	H-1	25	3.1	7.64	7.27	245	840	0.18
Household	Malibagh	Piped	H-2	24.7	0.56	7.17	7.17	329	540	0.22
Household	Uttara Sector 4	Piped	H-3	25	0.84	7.2	7.32	237	470	0.20
Household	Bashundhora	Piped	H-4	24.9	0.48	7.41	7.32	226	890	0.11

Table 14: Regrowth potential of collected drinking water sample

5. Conclusions and Recommendations:

5.1 Conclusions:

The following are the results of the evaluation of the test waters experiments:

1. Steel corrugated tin sheets with a thickness of 12 mm should be chosen from the market for SODIS applications because they hold the highest temperature during sun exposure. To improve the SODIS during the monsoon and winter seasons, reflective reactors (foil paper) should be placed on top of the sheets. SODIS' heating effect is a synergistic benefit that increases the system's overall efficiency.

2. There was relatively little fluctuation in the physicochemical parameters (temperature, turbidity, dissolved oxygen, and pH) of the test fluids (TW-1 and TW-2) or the reactors (PET bottle and plastic bag) over the monsoon and winter seasons. However, the EC value fluctuated before and after the trial.

3. The addition of H2O2 improved the inactivation of E. coli in the monsoon and winter.

4.During the monsoon season, LRV 5.2 achieved maximum efficiency with a bacterial inactivation period of only one hour in a plastic bag. And LRV 6.7 was discovered to be the most effective in a PET bottle, requiring only 2 hours of bacterial inactivation time.

5. The greatest results were obtained during the winter season with LRV 5.49, which had a bacterial inactivation time of only 2 hours in a PET bottle. The LRV for bacterial inactivation in the plastic bag, on the other hand, was 2. This reveals that the performance of SODIS with H2O2 in reactors (PET bottles and PB) was reasonably equal over the winter season.

6. Regardless of the monsoon period, sun exposure was larger during the monsoon season than during the winter.

7. After 12 and 24 hours of SODIS with H2O2, no microorganisms were found to have grown back in either of the test waters (TW-1 and TW-2) or in either of the reactors (PET bottle or plastic bag), indicating that the photocatalyst application inhibited E. coli regrowth in the treated water. This study shown that the combination of SODIS and H2O2 is one of the most effective ways for preventing microbial growth following treatment.

8. According to WHO criteria, the regeneration potential Delta LRV value for PET and plastic bags throughout the monsoon and winter seasons was greater than 5, indicating that they were a "highly protective" HWT system.

9. According to the results of the Weibull bacterial inactivation model, it takes less than an hour in

both the monsoon and the winter to achieve 4 log inactivation of germs in a PET bottle or a plastic bag. In all experiments, the R2 values were more than 0.95, indicating the precision of the SODIS experiment carried out in this investigation. All NRMSE values are less than 10%, indicating that the experiment performed admirably in comparison to prior investigations.

10. During the monsoon season, the maximum permissible exposure duration for a 4 LRV PET bottle is 2 hours. and winter seasons, while a polyethylene bag's acceptable exposure period is only one hour.

5.2 Future Scopes:

Drinking water microbial contamination is one of the primary causes of many water-borne illnesses in Bangladesh, and further study is needed to remove it utilizing accessible HWT alternatives such as SODIS. SODIS can be improved in the following ways.

1. Laboratory tests are necessary to evaluate the efficiency of SODIS inactivating species other than bacteria in drinking water, such as protozoa and spore-forming organisms.

2. In SODIS with H2O2 application, suitable care must be taken to check the presence of hydrogen peroxide following SODIS treatment, ensuring that no residual peroxide levels that might affect human health remain.

3. Heat-absorbing bitumen can be used in lieu of black enamel paints on corrugated tin sheets to raise the temperature of tin sheets that will aid in increasing the temperature of the water.

4. Future studies might look at the use of TiO2 as a photocatalyst in SODIS and its effects in comparison to the climatic conditions of Bangladesh.

5. SODIS photodegradation of PET bottles and plastic bags should be investigated microplastics, which are dangerous to humans if consumed, will be studied in the future.

6. Appropriate government entities in this nation should educate the public and advocate for the implementation of long-term remedies, such as SODIS, to eliminate waterborne diseases microorganisms, and strive for a future in which everyone has access to clean drinking water.

REFERENCES

A. Sychev, V. Isak, Iron compounds and the mechanisms of the homogeneous catalysis of the activation of O2 and H_2O_2 and of the oxidation of organic substrates, Russian Chem. Rev. 65 (1995) 1105–1129.

Acra, A., Karahagopian, Y., and Raffoul, Z. (1984). Solar Disinfection of Drinking Water and Oral Rehydration Solutions. 56. https://www.ircwash.org/sites/default/files/254.1-2847.pdf

Al-Gheethi, A. A. S., Norli, I., and Kadir, M. O. A. (2013). Elimination of enteric indicators and pathogenic bacteria in secondary effluents and lake water by solar disinfection (SODIS). Journal of Water Reuse and Desalination, 3(1), 39–46. https://doi.org/10.2166/wrd.2013.060

Alrousan, D. M. A., Polo-López, M. I., Dunlop, P. S. M., Fernández-Ibáñez, P., and Byrne, J. A. (2012). Solar photocatalytic disinfection of water with immobilised titanium dioxide in re- circulating flow CPC reactors. Applied Catalysis B: Environmental, 128, 126–134. https://doi.org/10.1016/j.apcatb.2012.07.038

Amin, M. T., and Han, M. Y. (2011). Improvement of solar based rainwater disinfection by using lemon and vinegar as catalysts. Desalination, 276(1–3), 416–424. https://doi.org/10.1016/j.desal.2011.03.076

Amirsoleimani, A., and Brion, G. M. (2021). Solar disinfection of turbid hygiene waters in Lexington, KY, USA. Journal of Water and Health, 19(4), 642–656. https://doi.org/10.2166/WH.2021.003

Ananthaswamy, H. N., and Eisenstark, A. (1976). Near-Uv-Induced Breaks in Phage Dna: Sensitization By Hydrogen Peroxide (a Tryptophan Photoproduct). Photochemistry and Photobiology, 24(5), 439–442. https://doi.org/10.1111/j.1751-1097.1976.tb06851.x

Ananthaswamy, H. N., Hartman, P. S., and Eisenstark, A. (1979). Synergistic Lethality of Phage T7 By Near-Uv Radiation and Hydrogen Peroxide: an Action Spectrum. Photochemistry and Photobiology, 29(1), 53–56. https://doi.org/10.1111/j.1751-1097.1979.tb09259.x

Arnold, B., Arana, B., Mäusezahl, D., Hubbard, A., and Colford, J. M. (2009). Evaluation of a pre- existing, 3-year household water treatment and handwashing intervention in rural Guatemala. International Journal of Epidemiology, 38(6), 1651–1661. https://doi.org/10.1093/ije/dyp241

Asiimwe, J. K., Quilty, B., Muyanja, C. K., and McGuigan, K. G. (2013). Field comparison of solar water disinfection (SODIS) efficacy between glass and polyethylene terephalate (PET) plastic bottles under sub-Saharan weather conditions. Journal of Water and Health, 11(4), 729–737. https://doi.org/10.2166/wh.2013.197

Azamzam, A. A., Rafatullah, M., Yahya, E. B., Ahmad, M. I., Lalung, J., Alharthi, S., Alosaimi, A. M., and Hussein, M. A. (2021). Insights into solar disinfection enhancements for drinking water treatment applications. Sustainability (Switzerland), 13(19), 10570. https://doi.org/10.3390/su131910570

Bain, R., Cronk, R., Hossain, R., Bonjour, S., Onda, K., Wright, J., Yang, H., Slaymaker, T., Hunter, P., Prüss-Ustün, A., and Bartram, J. (2014). Global assessment of exposure to faecal contamination through drinking water based on a systematic review. Tropical Medicine and International Health, 19(8), 917–927. https://doi.org/10.1111/TMI.12334

Barron, J. J., & Ashton, C. (2005). The effect of temperature on conductivity measurement. TSP, 7(3), 1-5.

Berney, M., Weilenmann, H. U., and Egli, T. (2006). Flow-cytometric study of vital cellular functions in Escherichia coli during solar disinfection (SODIS). Microbiology, 152(6), 1719–1729. https://doi.org/10.1099/mic.0.28617-0

Berney, M., Weilenmann, H. U., Simonetti, A., and Egli, T. (2006). Efficacy of solar disinfection of Escherichia coli, Shigella flexneri, Salmonella Typhimurium and Vibrio cholerae. Journal of Applied Microbiology, 101(4), 828–836. https://doi.org/10.1111/J.1365-2672.2006.02983.X

Bitew, B. D., Gete, Y. K., Biks, G. A., and Adafrie, T. T. (2018). The effect of SODIS water treatment intervention at the household level in reducing diarrheal incidence among children under 5 years of age: A cluster randomized controlled trial in Dabat district, northwest Ethiopia. Trials, 19(1), 1–15. https://doi.org/10.1186/s13063-018-2797-y

Bholay, A. D., and Nalawade, P. M. (2017). SODIS: A potent technology for sustainable drinking water management in tropics. Research Journal of Recent Sciences, 6(6), 29–34. https://www.researchgate.net/publication/317548953

Bosshard, F., Berney, M., Scheifele, M., Weilenmann, H. U., and Egli, T. (2009). Solar disinfection (SODIS) and subsequent dark storage of Salmonella typhimurium and Shigella flexneri monitored by flow cytometry. Microbiology, 155(4), 1310–1317. https://doi.org/10.1099/mic.0.024794-0

Bosshard, F., Bucheli, M., Meur, Y., and Egli, T. (2010). The respiratory chain is the cell's Achilles' heel during UVA inactivation in Escherichia coli. Microbiology, 156(7), 2006–2015. https://doi.org/10.1099/mic.0.038471-0

Bosshard, F., Riedel, K., Schneider, T., Geiser, C., Bucheli, M., and Egli, T. (2010). Protein oxidation and aggregation in UVA-irradiated Escherichia coli cells as signs of accelerated cellular senescence. Environmental Microbiology, 12(11), 2931–2945. https://doi.org/10.1111/j.1462-2920.2010.02268.x

Boyle, M., Sichel, C., Fernández-Ibáñez, P., Arias-Quiroz, G. B., Iriarte-Puña, M., Mercado, A., Ubomba-Jaswa, E., and McGuigan, K. G. (2008). Bactericidal effect of solar water disinfection under real sunlight conditions. Applied and Environmental Microbiology, 74(10), 2997–3001. https://doi.org/10.1128/AEM.02415-07/ASSET/7C9483E3-02DC-4254-892C-43C1548E4354/ASSETS/GRAPHIC/ZAM0100888640001.JPEG

Brockliss, S., Luwe, K., Ferrero, G., and Morse, T. (2022). Assessment of the 20L SODIS bucket household water treatment technology under field conditions in rural Malawi. International Journal of Hygiene and Environmental Health, 240(July 2021), 113913.

https://doi.org/10.1016/j.ijheh.2021.113913

Cadenas, E., and Davies, K. J. A. (2000). Mitochondrial free radical generation, oxidative stress, and aging. Free Radical Biology and Medicine, 29(3–4), 222–230. https://doi.org/10.1016/S0891-5849(00)00317-8

Cano Ssemakalu, C., Ubomba-Jaswa, E., Mamotswere Motaung, K. S. C., and Pillay, M. (2020). Solar inactivated Vibrio cholerae induces maturation of JAWS II dendritic cell line in vitro. Journal of Water and Health, 18(4), 494–504. https://doi.org/10.2166/WH.2020.040

Carratalà, A., Calado, A. D., Mattle, M. J., Meierhofer, R., Luzi, S., and Kohn, T. (2016). Solar disinfection of viruses in polyethylene terephthalate bottles. Applied and Environmental Microbiology, 82(1), 279–288. https://doi.org/10.1128/AEM.02897-15

Caslake, L. F., Connolly, D. J., Menon, V., Duncanson, C. M., Rojas, R., and Tavakoli, J. (2004). Disinfection of Contaminated Water by Using Solar Irradiation. Applied and Environmental Microbiology, 70(2), 1145–1150. https://doi.org/10.1128/AEM.70.2.1145-

1150.2004/ASSET/8ED77C58-F902-4229-8C6B-58B200A16EFB/ASSETS/GRAPHIC/ZAM0020413990005.JPEG

Castro-Alférez, M., Inmaculada Polo-López, M., Marugán, J., and Fernández-Ibáñez, P. (2018). Validation of a solar-thermal water disinfection model for Escherichia coli inactivation in pilot scale solar reactors and real conditions. Chemical Engineering Journal, 331, 831–840. https://doi.org/10.1016/j.cej.2017.09.015

Castro-Alférez, M., Polo-López, M. I., Marugán, J., and Fernández-Ibáñez, P. (2017). Mechanistic modeling of UV and mild-heat synergistic effect on solar water disinfection. Chemical Engineering Journal, 316, 111–120. https://doi.org/10.1016/j.cej.2017.01.026

Chapra, S. C. (2008). Surface water-quality modeling. Waveland press.

Charles, K. J., Ong, L. A., Achi, N. el, Ahmed, K. M., and Khan, M. R. (2021). Bangladesh MICS 2019: Water Quality Thematic Report. 110. https://psb.gov.bd/policies/wqtr2019.pdf

Chatterjee, S., and Hadi, A. S. (2006). Regression analysis by example. John Wiley \and Sons.

Chaúque, B. J. M., and Rott, M. B. (2021). Solar disinfection (SODIS) technologies as alternative for large-scale public drinking water supply: Advances and challenges. Chemosphere, 281, 130754. https://doi.org/10.1016/j.chemosphere.2021.130754

Chaúque, B. J. M., Chicumbe, C. M., Cossa, V. C., and Rott, M. B. (2021). Spatial arrangement of well and latrine and their influence on water quality in clayey soil – a study in low-income peri-urban neighborhoods in Lichinga, Mozambique. Journal of Water, Sanitation and Hygiene for Development, 11(2), 241–254. https://doi.org/10.2166/WASHDEV.2021.137

Chidya, R. C. G., Munthali, A. K., Chitedze, I., and Chitawo, M. L. (2021). Design and efficacy of solar disinfection system for improved rural household water treatment. Journal of Sustainable Development of Energy, Water and Environment Systems, 9(4). https://doi.org/10.13044/j.sdewes.d8.0369

Chihomvu, P. (2019). Investigating the intracellular growth, cytotoxicity and apoptotic effects of solar irradiated Campylobacter jejuni in a murine macrophage cell line (RAW 264.7). 2. https://doi.org/10.17632/2VWX9BC9B2.2

Chihomvu, P., Ssemakalu, C. C., Ubomba-Jaswa, E., and Pillay, M. (2021). Investigating the intracellular growth, cytotoxicity, and apoptotic effects of solar irradiated Campylobacter jejuni in a murine macrophage cell line (RAW 264.7). Journal of Biotech Research, 12, 52–64. https://doi.org/10.17632/2VWX9BC9B2.2

Clarizia, L., Russo, D., di Somma, I., Marotta, R., and Andreozzi, R. (2017). Homogeneous photo-

Fenton processes at near neutral pH: A review. Applied Catalysis B: Environmental, 209, 358–371. https://doi.org/10.1016/J.APCATB.2017.03.011

Clasen, T. (2008). Scaling Up Household Water Treatment: Looking Back , Seeing Forward. Public Health and the Environment, World Health Organization, Geneva.

Clasen, T., Roberts, I., Rabie, T., and Cairncross, S. (2004). Interventions to improve water quality for preventing diarrhoea. Cochrane Database of Systematic Reviews, 2. https://doi.org/10.1002/14651858.cd004794

Conroy, R. M., Elmore Meegan, M., Joyce, T., McGuigan, K., and Barnes, J. (1999). Solar disinfection of water reduces diarrhoeal disease: An update. Archives of Disease in Childhood, 81(4), 337–338. https://doi.org/10.1136/adc.81.4.337

Conroy, R. M., Elmore-Meegan, M., Joyce, T., McGuigan, K. G., and Barnes, J. (1996). Solar disinfection of drinking water and diarrhoea in Maasai children: a controlled field trial. The Lancet, 348(9043), 1695–1697. https://doi.org/10.1016/S0140-6736(96)02309-4

Conroy, R. M., Meegan, M. E., Joyce, T., McGuigan, K., and Barnes, J. (2001). Solar disinfection of drinking water protects against cholera in children under 6 years of age. Archives of Disease in Childhood, 85(4), 293–295. https://doi.org/10.1136/ADC.85.4.293

Cowie, B. E., Porley, V., and Robertson, N. (2020). Solar Disinfection (SODIS) Provides a Much Underexploited Opportunity for Researchers in Photocatalytic Water Treatment (PWT). ACS Catalysis, 10(20), 11779–11782. https://doi.org/10.1021/acscatal.0c03325

de Oliveira Filho, A. A., and Lima Neto, I. E. (2017). Modelagem da qualidade da água do rio Poti em Teresina (PI). Engenharia Sanitaria e Ambiental, 23(1), 3–14. https://doi.org/10.1590/S1413-41522017142354

du Preez, M., Conroy, R. M., Ligondo, S., Hennessy, J., Elmore-Meegan, M., Soita, A., and McGuigan, K. G. (2011). Randomized intervention study of solar disinfection of drinking water in the prevention of dysentery in Kenyan children aged under 5 years. Environmental Science and Technology, 45(21), 9315–9323. https://doi.org/10.1021/es2018835

du Preez, M., McGuigan, K. G., and Conroy, R. M. (2010). Solar disinfection of drinking water in the prevention of dysentery in South African children aged under 5 years: The role of participant motivation. Environmental Science and Technology, 44(22), 8744–8749. https://doi.org/10.1021/es103328j

Duarte, I., Rotter, A., Malvestiti, A., and Silva, M. (2009). The role of glass as a barrier against the transmission of ultraviolet radiation: An experimental study. Photodermatology Photoimmunology and Photomedicine, 25(4), 181–184. https://doi.org/10.1111/j.1600-0781.2009.00434.x

Eleren, S. C., Alkan, U., & Teksoy, A. (2014). Inactivation of E. Coli and B. Subtilis by solar and solar/H2O2 processes in humic surface waters. Fresen. Environ. Bull, 23, 1397-1406.

El-Seesy, I. E., Kamel, M., Khattab, N., and Hassan, S. A. (2016). Solar Disinfection of Drinking Water with Polyethylene Terephthalate Bottles Coated with Nano-Titanium Dioxide. International Journal of Advanced Engineering Research and Science (IJAERS), 3(7), 2456–1908. www.ijaers.com

Environmental Conservation Rule (2023), Bangladesh Gazette, Ministry of Environment and Forest, Government of the People’s Republic of Bangladesh.

F. Haber, J. Weiss, The catalytic decomposition ofhydrogen peroxide by iron salts, Proc. R. Soc. Lond. Ser. A 147 (861) (1934) 332–351.

Feachem, R., Bradley, D., Garelick, H., and Mara, D. (1983). Sanitation and disease: health aspects of excreta and wastewater management. https://www.cabdirect.org/cabdirect/abstract/19852018217

Fernàndez-Ibañez, P., McGuigan, K. G., and Fatta-Kassinos, D. (2017). Can solar water-treatment really help in the fight against water shortages? Europhysics News, 48(3), 26–30. https://doi.org/10.1051/epn/2017304

Feuerstein, O., Moreinos, D., and Steinberg, D. (2006). Synergic antibacterial effect between visible light and hydrogen peroxide on Streptococcus mutans. Journal of Antimicrobial Chemotherapy, 57(5), 872–876. https://doi.org/10.1093/JAC/DKL070

Figueredo-Fernández, M., Gutiérrez-Alfaro, S., Acevedo-Merino, A., and Manzano, M. A. (2017). Estimating lethal dose of solar radiation for enterococcus inactivation through radiation reaching the water layer. Application to Solar Water Disinfection (SODIS). Solar Energy, 158, 303–310. https://doi.org/10.1016/J.SOLENER.2017.09.006

Fisher, M. B., and Nelson, K. L. (2014). Inactivation of Escherichia coli by polychromatic simulated sunlight: Evidence for and implications of a fenton mechanism involving iron, hydrogen peroxide, and superoxide. Applied and Environmental Microbiology, 80(3), 935–942. https://doi.org/10.1128/AEM.02419-13

Fisher, M. B., Iriarte, M., and Nelson, K. L. (2012). Solar water disinfection (SODIS) of Escherichia coli, Enterococcus spp., and MS2 coliphage: Effects of additives and alternative container materials. Water Research, 46(6), 1745–1754. https://doi.org/10.1016/j.watres.2011.12.048

Fisher, M. B., Keenan, C. R., Nelson, K. L., and Voelker, B. M. (2008). Speeding up solar disinfection (SODIS): Effects of hydrogen peroxide, temperature, pH, and copper plus ascorbate on the photoinactivation of E. coli. Journal of Water and Health, 6(1), 35–51. https://doi.org/10.2166/wh.2007.005

Fisher, M. 2004 Speeding up Solar Disinfection: Effects of Hydrogen Peroxide, Temperature, and Copper plus Ascorbate on the Photoinactivation of E. coli in Charles River Water. Massachusetts Institute of Technology, Cambridge, MA, USA.

Fjendbo Jørgensen, A. J., Nøhr, K., Sørensen, H., and Boisen, F. (1998). Decontamination of drinking water by direct heating in solar panels. Journal of Applied Microbiology, 85(3), 441–447. https://doi.org/10.1046/j.1365-2672.1998.853497.x

Fraga, R. F., Rocha, S. M. G., and Lima Neto, I. E. (2020). Impact of flow conditions on coliform dynamics in an urban lake in the Brazilian semiarid. Https://Doi.Org/10.1080/1573062X.2020.1734948, 17(1), 43–53. https://doi.org/10.1080/1573062X.2020.1734948

García-Fernández, I., Miralles-Cuevas, S., Oller, I., Malato, S., Fernández-Ibáñez, P., and Polo-López, M. I. (2019). Inactivation of E. coli and E. faecalis by solar photo-Fenton with EDDS complex at neutral pH in municipal wastewater effluents. Journal of Hazardous Materials, 85–93. https://doi.org/10.1016/j.jhazmat.2018.07.037

García-Fernández, I., Polo-López, M. I., Oller, I., and Fernández-Ibáñez, P. (2012). Bacteria and fungi inactivation using Fe3+/sunlight, H_2O_2 /sunlight and near neutral photo-Fenton: A comparative study. Applied Catalysis B: Environmental, 121–122, 20–29. https://doi.org/10.1016/J.APCATB.2012.03.012

García-Gil, Á., García-Muñoz, R. A., McGuigan, K. G., and Marugán, J. (2021). Solar water disinfection to produce safe drinking water. A review of parameters, enhancements, and modelling approaches to make SODIS faster and safer. Molecules, 26(11), 1–27. https://doi.org/10.3390/molecules26113431

Geeraerd, A. H., Valdramidis, V. P., and van Impe, J. F. (2005). GInaFiT, a freeware tool to assess non-log-linear microbial survivor curves. International Journal of Food Microbiology, 102(1), 95–105. https://doi.org/10.1016/J.IJFOODMICRO.2004.11.038

Gelover, S., Gómez, L. A., Reyes, K., and Teresa Leal, M. (2006). A practical demonstration of water disinfection using TiO_2 films and sunlight. Water Research, 40(17), 3274–3280. https://doi.org/10.1016/j.watres.2006.07.006

Giannakis, S., Darakas, E., Escalas-Cañellas, A., and Pulgarin, C. (2014). Elucidating bacterial regrowth: Effect of disinfection conditions in dark storage of solar treated secondary effluent. Journal of Photochemistry and Photobiology A: Chemistry, 290(1), 43–53. https://doi.org/10.1016/j.jphotochem.2014.05.016

Giannakis, S., Darakas, E., Escalas-Cañellas, A., and Pulgarin, C. (2015). Solar disinfection modeling and post-irradiation response of Escherichia coli in wastewater. Chemical Engineering Journal, 281, 588–598. https://doi.org/10.1016/j.cej.2015.06.077

Giannakis, S., López, M. I. P., Spuhler, D., Pérez, J. A. S., Ibáñez, P. F., and Pulgarin, C. (2016a). Solar disinfection is an augmentable, in situ-generated photo-Fenton reaction-Part 2: A review of the applications for drinking water and wastewater disinfection. Applied Catalysis B: Environmental, 198, 431–446. https://doi.org/10.1016/j.apcatb.2016.06.007

Giannakis, S., Polo López, M. I., Spuhler, D., Sánchez Pérez, J. A., Fernández Ibáñez, P., and Pulgarin, C. (2016b). Solar disinfection is an augmentable, in situ-generated photo-Fenton reaction—Part 1: A review of the mechanisms and the fundamental aspects of the process. Applied Catalysis B: Environmental, 199, 199–223. https://doi.org/10.1016/j.apcatb.2016.06.009

Gill, L. W., and Price, C. (2010). Preliminary observations of a continuous flow solar disinfection system for a rural community in Kenya. Energy, 35(12), 4607–4611. https://doi.org/10.1016/j.energy.2010.01.008

Gizachew, M., Admasie, A., Wegi, C., and Assefa, E. (2020). Bacteriological Contamination of Drinking Water Supply from Protected Water Sources to Point of Use and Water Handling Practices among Beneficiary Households of Boloso Sore Woreda, Wolaita Zone, Ethiopia. International Journal of Microbiology, 2020, 5340202. https://doi.org/10.1155/2020/5340202

Goldstein, S., Aschengrau, D., Diamant, Y., and Rabani, J. (2007). Photolysis of Aqueous H_2O_2 : Quantum Yield and Applications for Polychromatic UV Actinometry in Photoreactors. Environmental Science and Technology, 41(21), 7486–7490. https://doi.org/10.1021/ES071379T

Gómez-Couso, H., Fontán-Sainz, M., McGuigan, K. G., and Ares-Mazás, E. (2009). Effect of the radiation intensity, water turbidity and exposure time on the survival of Cryptosporidium during simulated solar disinfection of drinking water. Acta Tropica, 112(1), 43–48. https://doi.org/10.1016/J.ACTATROPICA.2009.06.004

Graf, J., Togouet, S. Z., Kemka, N., Niyitegeka, D., Meierhofer, R., and Pieboji, J. G. (2010). Health gains from solar water disinfection (SODIS): evaluation of a water quality intervention in Yaoundé, Cameroon. Journal of Water and Health, 8(4), 779–796. https://doi.org/10.2166/WH.2010.003

Griffiths, J. K. (2016). Waterborne Diseases. In International Encyclopedia of Public Health (Second Edi, Vol. 7). Elsevier. https://doi.org/10.1016/B978-0-12-803678-5.00490-2

Grimm, B. (2004). Bottles for our health. Report of the SODIS Dissemination Project. Phase II: April 2003--March 2004.

Gupta, S. (2018). Sodis an Emerging Paradise for Treating Roof-Top Harvested Sodis an Emerging Paradise for Treating Roof-Top. May.

Gurung, P., Grimm, B., and Autenrieth, M. A. (2009). Disseminating the SODIS method: Which approach is most effective? Waterlines, 28(2), 130–143. https://doi.org/10.3362/1756-3488.2009.014

Gutiérrez-Alfaro, S., Acevedo, A., Figueredo, M., Saladin, M., and Manzano, M. A. (2017). Accelerating the process of solar disinfection (SODIS) by using polymer bags. Journal of Chemical Technology and Biotechnology, 92(2), 298–304. https://doi.org/10.1002/JCTB.5005

Gutiérrez-Alfaro, S., Rueda-Márquez, J. J., Perales, J. A., and Manzano, M. A. (2018). Combining sun-based technologies (microalgae and solar disinfection) for urban wastewater regeneration. Science of the Total Environment, 619–620, 1049–1057. https://doi.org/10.1016/j.scitotenv.2017.11.110

Haddad, J. S., Hindiyeh, M. Y., Hasan, W. O., and Lahham, M. M. . Solar Disinfection of Drinking Water Using Sand as a UV-Light Amplifier.

Halliwell, B. & Gutteridge, J. 1999 Free radicals in biology and medicine. Oxford University Press, Oxford, UK.

Halliwell, B., and Aruoma, O. I. (1991). DNA damage by oxygen-derived species Its mechanism and measurement in mammalian systems. FEBS Letters, 281(1–2), 9–19.

Halliwell, B., and Gutteridge, J. M. C. (1984). Oxygen toxicity, oxygen radicals, transition metals and disease. Biochemical Journal, 219(1), 1–14. https://doi.org/10.1042/bj2190001

Harding, A. S., and Schwab, K. J. (2012). Using Limes and Synthetic Psoralens to Enhance Solar Disinfection of Water (SODIS): A Laboratory Evaluation with Norovirus, Escherichia coli, and MS2. The American Journal of Tropical Medicine and Hygiene, 86(4), 566. https://doi.org/10.4269/AJTMH.2012.11-0370

Hartman, P. S., and Eisenstark, A. (1978). Synergistic killing of Escherichia coli by near-UV radiation and hydrogen peroxide: distinction between recA-repairable and recA-nonrepairable damage. Journal of Bacteriology, 133(2), 769–774. https://doi.org/10.1128/JB.133.2.769-774.1978

Hartman, P. S., and Eisenstark, A. (1980). Killing of Escherichia coli K-12 by near-ultraviolet radiation in the presence of hydrogen peroxide: Role of double-strand DNA breaks in absence of recombinational repair. Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis, 72(1), 31–42. https://doi.org/10.1016/0027-5107(80)90217-1

Heaselgrave, W., and Kilvington, S. (2010). Antimicrobial Activity of Simulated Solar Disinfection against Bacterial, Fungal, and Protozoan Pathogens and Its Enhancement by Riboflavin. Applied and Environmental Microbiology, 76(17), 6010–6012. https://doi.org/10.1128/AEM.00445-10

Heaselgrave, W., Patel, N., Kilvington, S., Kehoe, S. C., and McGuigan, K. G. (2006). Solar disinfection of poliovirus and Acanthamoeba polyphaga cysts in water - A laboratory study using simulated sunlight. Letters in Applied Microbiology, 43(2), 125–130. https://doi.org/10.1111/j.1472-765X.2006.01940.x

Helali, S., Polo-López, M. I., Fernández-Ibáñez, P., Ohtani, B., Amano, F., Malato, S., and Guillard, C. (2014). Solar photocatalysis: A green technology for E. coli contaminated water disinfection. Effect of concentration and different types of suspended catalyst. Journal of Photochemistry and Photobiology A: Chemistry, 276, 31–40. https://doi.org/10.1016/j.jphotochem.2013.11.011

Henle, E. S., and Linn, S. (1997). Formation, prevention, and repair of DNA damage by iron/hydrogen peroxide. The Journal of Biological Chemistry, 272(31), 19095–19098. https://doi.org/10.1074/JBC.272.31.19095

Heri, S., and Mosler, H. J. (2008). Factors affecting the diffusion of solar water disinfection: A field study in Bolivia. Health Education and Behavior, 35(4), 541–560. https://doi.org/10.1177/1090198108321248

Hoerter, J., Pierce, A., Troupe, C., Epperson, J. & Eisenstark, A. 1996 Role of enterobactin and intracellular iron in cell lethality during near-UV irradiation in Escherichia coli. Photochem. Photobiol. 64(3), 537–541.

Hoerter, J.D., Arnold, A .A ., Kuczynska, D.A ., Shibuya, A ., Ward, C.S., Sauer, M.G., Gizachew, A., Hotchkiss, T.M., Fleming, T.J., Johnson, S., 2005. Effects of sub- lethal UVA irradiation on activity levels of oxidative defense enzymes and pro- tein oxidation in Escherichia coli. J. Photochem. Photobiol. B Biol. 81, 171–180. https://doi.org/10.1016/j.jphotobiol.20

Hunter, P. R. (2009). Household water treatment in developing countries: Comparing different intervention types using meta-regression. Environmental Science and Technology, 43(23), 8991–8997. https://doi.org/10.1021/es9028217

Imlay, J. A. (2003). Pathways of oxidative damge. Annual Review of Microbiology, 57, 395.

Imlay, J. A. (2008). Cellular Defenses against Superoxide and Hydrogen Peroxide. Https://Doi.Org/10.1146/Annurev.Biochem.77.061606.161055, 77, 755–776. https://doi.org/10.1146/ANNUREV.BIOCHEM.77.061606.161055

Imlay, J. A., and Linn, S. (1986). Bimodal pattern of killing of DNA-repair-defective or anoxically grown Escherichia coli by hydrogen peroxide. Journal of Bacteriology, 166(2), 519–527. https://doi.org/10.1128/JB.166.2.519-527.1986

Imlay, J. A., and Linn, S. (1988). DNA Damage and Oxygen Radical Toxicity. Science, 240(4857), 1302–1309. https://doi.org/10.1126/SCIENCE.3287616

Islam, M. A., Azad, A. K., Akber, M. A., Rahman, M., & Sadhu, I. (2015). Effectiveness of solar disinfection (SODIS) in rural coastal Bangladesh. Journal of water and health, 13(4), 1113-1122.

Islam, M. A., Sakakibara, H., Karim, M. R., Sekine, M., and Mahmud, Z. H. (2011). Bacteriological assessment of drinking water supply options in coastal areas of Bangladesh. Journal of Water and Health, 9(2), 415–428. https://doi.org/10.2166/WH.2011.114

J. Kiwi and, and Nadtochenko, V. (2005). Evidence for the Mechanism of Photocatalytic Degradation of the Bacterial Wall Membrane at the TiO_2 Interface by ATR-FTIR and Laser Kinetic Spectroscopy. Langmuir, 21(10), 4631–4641. https://doi.org/10.1021/LA046983L

Jang, S., and Imlay, J. A. (2007). Micromolar intracellular hydrogen peroxide disrupts metabolism by damaging iron-sulfur enzymes. Journal of Biological Chemistry, 282(2), 929–937. https://doi.org/10.1074/jbc.M607646200

Ji, M. F., and Wood, W. (2007). Purchase and consumption habits: Not necessarily what you intend. Journal of Consumer Psychology, 17(4), 261–276. https://doi.org/10.1016/S1057-7408(07)70037-2

Jones. (1999). Applications of Hydrogen Peroxide and Derivatives. Royal Society of Chemistry, 224. https://doi.org/10.1039/9781847550132

Juvakoski, A., Singhal, G., Manzano, M. A., Moriñigo, M. Á., Vahala, R., and Levchuk, I. (2022). Solar disinfection – An appropriate water treatment method to inactivate faecal bacteria in cold climates. Science of the Total Environment, 827.

https://doi.org/10.1016/j.scitotenv.2022.154086

Kalt, P., Birzer, C., Evans, H., Liew, A., Padovan, M., and Watchman, M. (2014). A solar disinfection water treatment system for remote communities. Procedia Engineering, 78, 250–258. https://doi.org/10.1016/j.proeng.2014.07.064

Karim, Md. R., Khan, Md. H. R. B., Akash, Md. A.-S.-A., and Shams, S. (2021). Effectiveness of solar disinfection for household water treatment: An experimental and modeling study. Journal of Water Sanitation and Hygiene for Development, 11(3), 374–385. https://doi.org/10.2166/washdev.2021.243

Karim, M. R. (2010). Microbial contamination and associated health burden of rainwater harvesting in Bangladesh. Water Science and Technology, 61(8), 2129-2135.

Kehoe, S. C., Joyce, T. M., Ibrahim, P., Gillespie, J. B., Shahar, R. A., and McGuigan, K. G. (2001). Effect of agitation, turbidity, aluminium foil reflectors and container volume on the inactivation efficiency of batch-process solar disinfectors. Water Research, 35(4), 1061–1065. https://doi.org/10.1016/S0043-1354(00)00353-5

Keogh, M. B., Castro-Alférez, M., Polo-López, M. I., Fernández Calderero, I., Al-Eryani, Y. A., Joseph-Titus, C., Sawant, B., Dhodapkar, R., Mathur, C., McGuigan, K. G., and Fernández-Ibáñez, P. (2015). Capability of 19-L polycarbonate plastic water cooler containers for efficient solar water disinfection (SODIS): Field case studies in India, Bahrain and Spain. Solar Energy, 116(June), 1–11. https://doi.org/10.1016/j.solener.2015.03.035

Keyer, K., and Imlay, J. A. (1996). Superoxide accelerates DNA damage by elevating free-iron levels. Proceedings of the National Academy of Sciences, 93(24), 13635–13640. https://doi.org/10.1073/PNAS.93.24.13635

Khedikar, I. P., Tembhurkar, A. R., Dabhekar, K. R., and Godboley, B. J. (2021). Effect of turbidity on survival of Escherichia coli, feacal coliform and total coliform in grey water by using solar disinfection (SODIS). Journal of Physics: Conference Series, 1913(1), 6–12. https://doi.org/10.1088/1742-6596/1913/1/012068

Klementová, S., Kříž, D., Kopáček, J., Novák, F., Porcal, P., Sci, P. P., Sirtori, C., Zapata, A., Malato, S., Gernjak, W., Fern, A. R., and Ag, A. (2009). 5th European Meeting on Solar Chemistry and Photocatalysis : Environmental Application Solar photocatalytic treatment of quinolones : intermediates and toxicity evaluation †. Photochemical and Photobiological Sciences, 8, 569–740.

Kohn, T., Mattle, M. J., Minella, M., and Vione, D. (2016). A modeling approach to estimate the solar disinfection of viral indicator organisms in waste stabilization ponds and surface waters. Water Research, 88, 912–922. https://doi.org/10.1016/j.watres.2015.11.022

Kraemer, S. M., and Mosler, H. J. (2010). Persuasion factors influencing the decision to use sustainable household water treatment. International Journal of Environmental Health Research, 20(1), 61–79. https://doi.org/10.1080/09603120903398301

Lawand, T. A., Alward, R., Odeyemi, O., Hahn, J., Kandpal, T. C., and Ayoub, J. (1990). Solar water disinfection: proceedings of a workshop held at the Brace Research Institute, Montreal, Que., Canada, 15-17 Aug. 1988. Manuscript Reports/IDRC; 231e.

Lee, S. K., Sheridan, M., and Mills, A. (2005). Novel UV-activated colorímetric oxygen indicator. Chemistry of Materials, 17(10), 2744–2751. https://doi.org/10.1021/CM0403863/ASSET/IMAGES/MEDIUM/CM0403863N00001.GIF

Lima, B. P., Mamede, G. L., and Lima Neto, I. E. (2018). Monitoramento e modelagem da qualidade de água em uma bacia hidrográfica semiárida. Engenharia Sanitaria e Ambiental, 23(1), 125–135. https://doi.org/10.1590/S1413-41522018167115

Liochev, S. I., and Fridovich, I. (1994). The role of O2.- in the production of HO.: in vitro and in vivo. Free Radical Biology and Medicine, 16(1), 29–33. https://doi.org/10.1016/0891-5849(94)90239-9

Luzi, S., Tobler, M., Suter, F., and Meierhofer, R. (2016). SODIS manual (Issue January 2002).

M.I. Polo-López, I. García-Fernández, I. Oller, P. Fernández-Ibá˜nez, Photochem- ical & Photobiologiacl Sciences 10 (2011) 381–388.

mac Mahon, J., and Gill, L. W. (2018). Sustainability of novel water treatment technologies in developing countries: Lessons learned from research trials on a pilot continuous flow solar water disinfection system in rural Kenya. Development Engineering, 3, 47–59. https://doi.org/10.1016/j.deveng.2018.01.003

Mafart, P., Couvert, O., Gaillard, S., and Leguerinel, I. (2002). On calculating sterility in thermal preservation methods: application of the Weibull frequency distribution model. International Journal of Food Microbiology, 72(1–2), 107–113. https://doi.org/10.1016/S0168-1605(01)00624-9

Mahvi, A. H. (2007). Feasibility of solar energy in disinfection of drinking water in Iran. American-Eurasian Journal of Agricultural and Environmental Science, 2(4), 407–410.

Mailhot, G., Sarakha, M., Lavedrine, B., Cáceres, J., and Malato, S. (2002). Fe(III)-solar light induced degradation of diethyl phthalate (DEP) in aqueous solutions. Chemosphere, 49(6), 525–532. https://doi.org/10.1016/S0045-6535(02)00418-6

Malato, S., Fernández-Ibáñez, P., Maldonado, M. I., and Oller, I. (2013). Solar Photocatalytic Processes: Water Decontamination and Disinfection. In New and Future Developments in Catalysis: Solar Photocatalysis. Elsevier B.V. https://doi.org/10.1016/B978-0-444-53872-7.00017-0

Malato, S., Fernández-Ibáñez, P., Maldonado, M. I., Blanco, J., and Gernjak, W. (2009). Decontamination and disinfection of water by solar photocatalysis: Recent overview and trends. Catalysis Today, 147(1), 1–59. https://doi.org/10.1016/J.CATTOD.2009.06.018

Marques, A. R., Gomes, F. de C. O., Fonseca, M. P. P., Parreira, J. S., and Santos, V. P. (2013). Efficiency of PET reactors in solar water disinfection for use in southeastern Brazil. Solar Energy, 87(1), 158–167. https://doi.org/10.1016/j.solener.2012.10.016

Martín-Domínguez, A., Alarcón-Herrera, M. T., Martín-Domínguez, I. R., and González-Herrera, A. (2005). Efficiency in the disinfection of water for human consumption in rural communities using solar radiation. Solar Energy, 78(1), 31–40. https://doi.org/10.1016/J.SOLENER.2004.07.005

Martínez-García, A., Vincent, M., Rubiolo, V., Domingos, M., Canela, M. C., Oller, I., Fernández-Ibáñez, P., and Polo-López, M. I. (2020). Assessment of a pilot solar V-trough reactor for solar water disinfection. Chemical Engineering Journal, 399(June), 125719. https://doi.org/10.1016/j.cej.2020.125719

Marugán, J., Giannakis, S., McGuigan, K. G., and Polo-López, I. (2020). Solar Disinfection as a Water Treatment Technology. 1–16. https://doi.org/10.1007/978-3-319-70061-8_125-1

Matlack, C., Chizeck, H., Davis, T. B., and Linnes, J. (2011). A low-cost solar disinfection indicator for safe water. Proceedings - 2011 IEEE Global Humanitarian Technology Conference, GHTC 2011, 283–286. https://doi.org/10.1109/GHTC.2011.81

Mathur, A. (2015). Conductivity: water quality assessment. Int. J. Eng. Res, 3(3).

Mäusezahl, D., Christen, A., Pacheco, G. D., Tellez, F. A., Iriarte, M., Zapata, M. E., Cevallos, M., Hattendorf, J., Cattaneo, M. D., Arnold, B., Smith, T. A., and Colford, J. M. (2009). Solar Drinking Water Disinfection (SODIS) to Reduce Childhood Diarrhoea in Rural Bolivia: A

Cluster-Randomized, Controlled Trial. PLOS Medicine, 6(8), e1000125. https://doi.org/10.1371/JOURNAL.PMED.1000125

Mbonimpa, E. G., Vadheim, B., and Blatchley, E. R. (2012). Continuous-flow solar UVB disinfection reactor for drinking water. Water Research, 46(7), 2344–2354. https://doi.org/10.1016/J.WATRES.2012.02.003

Mcguigan, K. G., Conroy, R. M., and Mosler, H.. Author ' s personal copy Solar water disinfection (SODIS): A review from bench-top to roof-top.

McGuigan, K. G., Conroy, R. M., Mosler, H.-J., Preez, M. du, Ubomba-Jaswa, E., and Fernandez-Ibañez, P. (2012). Solar water disinfection (SODIS): A review from bench-top to roof-top. Journal of Hazardous Materials, 235–236, 29–46. https://doi.org/10.1016/j.jhazmat.2012.07.053

McGuigan, K. G., Joyce, T. M., Conroy, R. M., Gillespie, J. B., and Elmore-Meegan, M. (1998). Solar disinfection of drinking water contained in transparent plastic bottles: Characterizing the bacterial inactivation process. Journal of Applied Microbiology, 84(6), 1138–1148. https://doi.org/10.1046/j.1365-2672.1998.00455.x

McGuigan, K. G., Samaiyar, P., du Preez, M., and Conroy, R. M. (2011). High compliance randomized controlled field trial of solar disinfection of drinking water and its impact on childhood diarrhea in rural Cambodia. Environmental Science and Technology, 45(18), 7862–7867. https://doi.org/10.1021/ES201313X/SUPPL_FILE/ES201313X_SI_002.PDF

McLoughlin, O. A., Fernández Ibáñez, P., Gernjak, W., Malato Rodriguez, S., and Gill, L. W. (2004). Photocatalytic disinfection of water using low cost compound parabolic collectors. Solar Energy, 77(5), 625–633. https://doi.org/10.1016/j.solener.2004.05.017

McLoughlin, O. A., Kehoe, S. C., McGuigan, K. G., Duffy, E. F., al Touati, F., Gernjak, W., Oller Alberola, I., Malato Rodríguez, S., and Gill, L. W. (2004). Solar disinfection of contaminated water: a comparison of three small-scale reactors. Solar Energy, 77(5), 657–664. https://doi.org/10.1016/J.SOLENER.2004.07.004

McMichael, S., Waso, M., Reyneke, B., Khan, W., Byrne, J. A., and Fernandez-Ibanez, P. (2021). Electrochemically assisted photocatalysis for the disinfection of rainwater under solar irradiation. Applied Catalysis B: Environmental, 281(August 2020), 119485. https://doi.org/10.1016/j.apcatb.2020.119485

Meierhofer, R., and Landolt, G. (2009). Factors supporting the sustained use of solar water disinfection - Experiences from a global promotion and dissemination programme. Desalination, 248(1–3), 144–151. https://doi.org/10.1016/j.desal.2008.05.050

Meierhofer, R., and Wegelin, M. (2002). Solar Disinfection of Water: A Guide for the Application of SODIS. https://ejurnal.bppt.go.id/index.php/JAI/article/view/2455

Mills, A., Lee, S. K., and Sheridan, M. (2005). Development of a novel UV indicator and dosimeter film. Analyst, 130(7), 1046–1051. https://doi.org/10.1039/B502969D

Montgomery, D. C., Peck, E. A., and Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley \and Sons.

Morse, T., Luwe, K., Lungu, K., Chiwaula, L., Mulwafu, W., Buck, L., Harlow, R., Fagan, G. H., and McGuigan, K. (2020). A Transdisciplinary Methodology for Introducing Solar Water Disinfection to Rural Communities in Malawi—Formative Research Findings. Integrated Environmental Assessment and Management, 16(6), 871–884. https://doi.org/10.1002/ieam.4249

Moser, S., and Mosler, H. J. (2008). Differences in influence patterns between groups predicting the adoption of a solar disinfection technology for drinking water in Bolivia. Social Science and Medicine, 67(4), 497–504. https://doi.org/10.1016/j.socscimed.2008.04.002

Mosler, H. J. (2005). Determinants of the diffusion of SODIS: A quantitative field study in Bolivia. Working Paper.

Mostafa, M. G. (2021). Scope of Solar Energy for Disinfection Water in Bangladesh. June. Mostafa,

M. G., and Han, M. Y. (2021). Utilization of Solar Energy for the Disinfection of Drinking Water in Bangladesh. July 2020.

Muela, A., García-Bringas, J. M., Seco, C., Arana, I., and Barcina, I. (2002). Participation of oxygen and role of exogenous and endogenous sensitizers in the photoinactivation of Escherichia coli by photosynthetically active radiation, UV-A and UV-B. Microbial Ecology, 44(4), 354–364. https://doi.org/10.1007/s00248-002-1027-y

Mustafa, A., Scholz, M., Khan, S., and Ghaffar, A. (2013). Application of solar disinfection for treatment of contaminated public water supply in a developing country: Field observations. Journal of Water and Health, 11(1), 135–145. https://doi.org/10.2166/wh.2012.119

Nalwanga, R., Quilty, B., Muyanja, C., Fernandez-Ibañez, P., and McGuigan, K. G. (2014). Evaluation of solar disinfection of E. coli under Sub-Saharan field conditions using a 25L borosilicate glass batch reactor fitted with a compound parabolic collector. Solar Energy, 100, 195–202. https://doi.org/10.1016/j.solener.2013.12.011

Narain, A, A., U, Kc., and SK, M. (2012). Feasibility of solar energy in disinfection of water source for an Indian village – a case study. International Journal Environtment Science, 2(4), 2338–2345. https://doi.org/10.6088/ijes.002 02030115

Navntoft, C., Araujo, P., Litter, M. I., Apella, M. C., Fernández, D., Puchulu, M. E., del Margarita, V. H., and Blesa, M. A. (2007). Field Tests of the Solar Water Detoxification SOLWATER Reactor in Los Pereyra, Tucumán, Argentina. Journal of Solar Energy Engineering, 129(1), 127–134. https://doi.org/10.1115/1.2391318

Navntoft, C., Ubomba-Jaswa, E., McGuigan, K. G., and Fernández-Ibáñez, P. (2008). Effectiveness of solar disinfection using batch reactors with non-imaging aluminium reflectors under real conditions: Natural well-water and solar light. Journal of Photochemistry and Photobiology B: Biology, 93(3), 155–161. https://doi.org/10.1016/j.jphotobiol.2008.08.002

Ndounla, J., and Pulgarin, C. (2014). Evaluation of the efficiency of the photo Fenton disinfection of natural drinking water source during the monsoon season in the Sahelian region. Science of The Total Environment, 493, 229–238. https://doi.org/10.1016/J.SCITOTENV.2014.05.139

Ndounla, J., Kenfack, S., Wéthé, J., and Pulgarin, C. (2014). Relevant impact of irradiance (vs. dose) and evolution of pH and mineral nitrogen compounds during natural water disinfection by photo-Fenton in a solar CPC reactor. Applied Catalysis B: Environmental, 148–149, 144–153. https://doi.org/10.1016/j.apcatb.2013.10.048

Ndounla, J., Spuhler, D., Kenfack, S., Wéthé, J., and Pulgarin, C. (2013). Inactivation by solar photo-Fenton in pet bottles of wild enteric bacteria of natural well water: Absence of re-growth after one week of subsequent storage. Applied Catalysis B: Environmental, 129, 309–317. https://doi.org/10.1016/j.apcatb.2012.09.016

Neal, D. T., Wood, W., and Quinn, J. M. (2006). Habits - A repeat performance. Current Directions in Psychological Science, 15(4), 198–202. https://doi.org/10.1111/j.1467-8721.2006.00435.x

Nelson, K. L., Boehm, A. B., Davies-Colley, R. J., Dodd, M. C., Kohn, T., Linden, K. G., Liu, Y., Maraccini, P. A., McNeill, K., Mitch, W. A., Nguyen, T. H., Parker, K. M., Rodriguez, R. A., Sassoubre, L. M., Silverman, A. I., Wigginton, K. R., and Zepp, R. G. (2018). Sunlight-mediated inactivation of health-relevant microorganisms in water: a review of mechanisms and modeling approaches. Environmental Science: Processes and Impacts, 20(8), 1089–1122. https://doi.org/10.1039/c8em00047f

Ng, T. W., An, T., Li, G., Ho, W. K., Yip, H. Y., Zhao, H., and Wong, P. K. (2015). The role and synergistic effect of the light irradiation and H_2O_2 in photocatalytic inactivation of Escherichia coli. Journal of Photochemistry and Photobiology B: Biology, 149, 164–171. https://doi.org/10.1016/j.jphotobiol.2015.06.007

Nwankwo, E. J., Agunwamba, J. C., and Nnaji, C. C. (2019). Effect of Radiation Intensity , Water Temperature and Support-Base Materials on the Inactivation Efficiency of Solar Water Disinfection (SODIS) Content courtesy of Springer Nature , terms of use apply . Rights reserved . Content courtesy of Springer Nat.

Nwankwo, E. J., Agunwamba, J. C., Igwe, S. E., and Odenigbo, C. (2022). Regression models for predicting the die-off rate of E. coli in solar water disinfection. Journal of Water Sanitation and Hygiene for Development, 12(8), 575–586. https://doi.org/10.2166/washdev.2022.056

Oates, P. M. (2001). Solar disinfection for point of use water treatment in Haiti. In Department of Civil and Environmental Engineering. Massachusetts Institute of Technology.

Oates, P. M., Shanahan, P., and Polz, M. F. (2003). Solar disinfection (SODIS): Simulation of solar radiation for global assessment and application for point-of-use water treatment in Haiti. Water Research, 37(1), 47–54. https://doi.org/10.1016/S0043-1354(02)00241-5

Ortega-Gómez, E., Martín, M. M. B., García, B. E., Pérez, J. A. S., and Ibáñez, P. F. (2016). Wastewater disinfection by neutral pH photo-Fenton: The role of solar radiation intensity. Applied Catalysis B: Environmental, 181, 1–6. https://doi.org/10.1016/j.apcatb.2015.06.059

Ozores Diez, P., Giannakis, S., Rodríguez-Chueca, J., Wang, D., Quilty, B., Devery, R., McGuigan, K., and Pulgarin, C. (2020). Enhancing solar disinfection (SODIS) with the photo-Fenton or the Fe2+/peroxymonosulfate-activation process in large-scale plastic bottles leads to toxicologically safe drinking water. Water Research, 186. https://doi.org/10.1016/j.watres.2020.116387

Pal, R., Kar, S., Tsering, D., and Rai, B. (2010). Solar disinfection improves drinking water quality to prevent diarrhea in under-five children in Sikkim, India. Journal of Global Infectious Diseases, 2(3), 221. https://doi.org/10.4103/0974-777x.68532

Park, S., You, X., and Imlay, J. A. (2005). Substantial DNA damage from submicromolar intracellular hydrogen peroxide detected in Hpx-mutants of Escherichia coli. Proceedings of the National Academy of Sciences, 102(26), 9317–9322.

Pichel, N., Vivar, M., and Fuentes, M. (2019). The problem of drinking water access: A review of disinfection technologies with an emphasis on solar treatment methods. Chemosphere, 218, 1014–1030. https://doi.org/10.1016/j.chemosphere.2018.11.205

Pignatello, J. J., Oliveros, E., and MacKay, A. (2007). Advanced Oxidation Processes for Organic Contaminant Destruction Based on the Fenton Reaction and Related Chemistry. Https://Doi.Org/10.1080/10643380500326564, 36(1), 1–84. https://doi.org/10.1080/10643380500326564

Polo-López, M. I., García-Fernández, I., Oller, I., and Fernández-Ibáñez, P. (2020). Solar disinfection of fungal spores in water aided by low concentrations of hydrogen peroxide. Photochemical and Photobiological Sciences 2011 10:3, 10(3), 381–388. https://doi.org/10.1039/C0PP00174K

Polo-López, M.I., Fernández-Ibáñez, P., Ubomba-Jaswa, E., Navntoft, C., García- Fernández, I., Dunlop, P.S.M., Schmid, M., Byrne, J.A., McGuigan, K.G., 2011. Elim- ination of water pathogens with solar radiation using an automated sequential batch CPC reactor. J Hazard Mater 196, 16–21. https://doi.org/10.1016/j.jhazmat. 2011.08.052 .

Quinones, M., Davis, B. M., and Waldor, M. K. (2006). Activation of the Vibrio cholerae SOS response is not required for intestinal cholera toxin production or colonization. Infection and Immunity, 74(2), 927–930. https://doi.org/10.1128/IAI.74.2.927-930.2006

Rai, B., Pal, R., Kar, S., and Tsering, D. C. (2010). Solar disinfection improves drinking water quality to prevent diarrhea in under-five children in Sikkim, India. Journal of Global Infectious Diseases, 2(3), 221. https://doi.org/10.4103/0974-777X.68532

Rainey, R. C., and Harding, A. K. (2005). Acceptability of solar disinfection of drinking water treatment in Kathmandu Valley, Nepal. International Journal of Environmental Health Research, 15(5), 361–372. https://doi.org/10.1080/09603120500289168

Rainwater Harvesting in Cities. (2015). Urban Water Reuse Handbook, 769–770.

Raes, P. Steduto, T.C. Hsiao, E. Fereres, Chapter 2. Users Guide, in AquaCrop Version 4.0, FAO, Land and Water Division, Rome, Italy, (2012).

Reed, R. H. (1997). Solar inactivation of faecal bacteria in water: The critical role of oxygen. Letters in Applied Microbiology, 24(4), 276–280. https://doi.org/10.1046/j.1472-765X.1997.00130.x

Reyneke, B., Ndlovu, T., Vincent, M. B., Martínez-García, A., Polo-López, M. I., Fernández-Ibáñez, P., Ferrero, G., Khan, S., McGuigan, K. G., and Khan, W. (2020). Validation of large-volume batch solar reactors for the treatment of rainwater in field trials in sub-Saharan Africa. Science of the Total Environment, 717, 137223. https://doi.org/10.1016/j.scitotenv.2020.137223

Rijal, G. K., and Fujioka, R. S. (2001). Synergistic effect of solar radiation and solar heating to disinfect drinking water sources. Water Science and Technology, 43(12), 155–162. https://doi.org/10.2166/WST.2001.0728

Rincón, A. G., and Pulgarin, C. (2004). Effect of pH, inorganic ions, organic matter and H_2O_2 on E. coli K12 photocatalytic inactivation by TiO_2: Implications in solar water disinfection. Applied Catalysis B: Environmental, 51(4), 283–302. https://doi.org/10.1016/j.apcatb.2004.03.007

Rincón, A. G., and Pulgarin, C. (2006). Comparative evaluation of Fe3+ and TiO_2 photoassisted processes in solar photocatalytic disinfection of water. Applied Catalysis B: Environmental, 63(3–4), 222–231. https://doi.org/10.1016/J.APCATB.2005.10.009

Rincón, A. G., and Pulgarin, C. (2007a). Fe3+ and TiO_2 solar-light-assisted inactivation of E. coli at field scale: Implications in solar disinfection at low temperature of large quantities of water. Catalysis Today, 122(1–2), 128–136. https://doi.org/10.1016/J.CATTOD.2007.01.028

Rincón, A. G., and Pulgarin, C. (2007b). Absence of E. coli regrowth after Fe3+ and TiO_2 solar photoassisted disinfection of water in CPC solar photoreactor. Catalysis Today, 124(3–4), 204–214. https://doi.org/10.1016/j.cattod.2007.03.039

Rosa e Silva, G. O., Loureiro, H. O., Soares, L. G., de Andrade, L. H., and Santos, R. G. L. (2022). Evaluation of an alternative household water treatment system based on slow filtration and solar disinfection. Journal of Water and Health, 20(1), 157–166. https://doi.org/10.2166/WH.2021.211

Rose, A., Roy, S., Abraham, V., Holmgren, G., George, K., Balraj, V., Abraham, S., Muliyil, J., Joseph, A., and Kang, G. (2006). Solar disinfection of water for diarrhoeal prevention in southern India. Archives of Disease in Childhood, 91(2), 139–141. https://doi.org/10.1136/ADC.2005.077867

Rubio, D., Nebot, E., Casanueva, J. F., and Pulgarin, C. (2013). Comparative effect of simulated solar light, UV, UV/H_2O_2 and photo-Fenton treatment (UV-Vis/H_2O_2 /Fe2+,3+) in the Escherichia coli inactivation in artificial seawater. Water Research, 47(16), 6367–6379. https://doi.org/10.1016/j.watres.2013.08.006

Saitoh, T. S., and El-Ghetany, H. H. (2002). A pilot solar water disinfecting system: performance analysis and testing. Solar Energy, 72(3), 261–269. https://doi.org/10.1016/S0038-092X(01)00102-5

Sajiki, J., and Yonekubo, J. (2004). Inhibition of seawater on bisphenol A (BPA) degradation by Fenton reagents. Environment International, 30(2), 145–150. https://doi.org/10.1016/S0160-4120(03)00155-7

Saladin, M. (2010). SODIS bags for humanitarian aid. March.

Samoili, S., Farinelli, G., Moreno-SanSegundo, J. Á., McGuigan, K. G., Marugán, J., Pulgarín, C., and Giannakis, S. (2022). Predicting the bactericidal efficacy of solar disinfection (SODIS): from kinetic modeling of in vitro tests towards the in silico forecast of E. coli inactivation. Chemical Engineering Journal, 427(1). https://doi.org/10.1016/j.cej.2021.130866

Santos, V. B., Machado, B. S., Atalla, A., Cavalheri, P. S., and Filho, F. J. C. M. (2020). Microbiological evaluation of constructed wetlands and solar disinfection in wastewater treatment and reuse. Journal of Water and Health, 18(6), 1146–1153. https://doi.org/10.2166/wh.2020.301

Sciacca, F., Rengifo-Herrera, J. A., Wéthé, J., and Pulgarin, C. (2010). Dramatic enhancement of solar disinfection (SODIS) of wild Salmonella sp. in PET bottles by H_2O_2 addition on natural water of Burkina Faso containing dissolved iron. Chemosphere, 78(9), 1186–1191. https://doi.org/10.1016/j.chemosphere.2009.12.001

Seaver, L. C., and Imlay, J. A. (2001). Hydrogen peroxide fluxes and compartmentalization inside growing Escherichia coli. Journal of Bacteriology, 183(24), 7182–7189. https://doi.org/10.1128/JB.183.24.7182-7189.2001/ASSET/4EFBC2F1-56DE-4A5D-8380-4E216091747E/ASSETS/GRAPHIC/JB2410847004.JPEG

Shrigondekar, A., and Ullagaddi, P. (2021). A Review on Improving Bearing Capacity of Soil by Effective Use of Geosynthetic Reinforcement. In Lecture Notes in Civil Engineering (Vol. 87). https://doi.org/10.1007/978-981-15-6463-5_53

Sichel, C. (2009). P. Fernández-Ibá nez, M. de Cara, J. Tello. Water Res, 43(7), 1841–1850.

Sichel, C., Fernández-Ibáñez, P., de Cara, M., and Tello, J. (2009). Lethal synergy of solar UV-radiation and H_2O_2 on wild Fusarium solani spores in distilled and natural well water. Water Research, 43(7), 1841–1850.

Sikka, V., Chattu, V. K., Popli, R. K., Galwankar, S. C., Kelkar, D., Sawicki, S. G., Stawicki, S. P., and Papadimos, T. J. (2016). The emergence of zika virus as a global health security threat: A review and a consensus statement of the INDUSEM Joint working Group (JWG). Journal of Global Infectious Diseases, 8(1), 3–15. https://doi.org/10.4103/0974-777X.176140

Siriwong, C., & Holasut, K. (2006, January). The Coupling effect between heat and UV irradiation in the solar disinfection for drinking water in the PET bottles. In Conference proceedings of Technology and Innovation for Sustainable Development Conference (TISD2006) Faculty of Engineering, Khon Kaen University, Thailand. https://www. academia. edu/22458971/The_Coupling_effect_between_heat.

Sobsey, M. D., Stauber, C. E., Casanova, L. M., Brown, J. M., and Elliott, M. A. (2008). Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world. Environmental Science and Technology, 42(12), 4261–4267. https://doi.org/10.1021/es702746n

SODIS (2022), how does it work? Retrieved October 4, 2022, from https://www.sodis.ch/

Sommer, B., Marino, A., Solarte, Y., Salas, M. L., Dierolf, C., Valiente, C., Mora, D., Rechsteiner, R., Setter, P., Wirojanagud, W., and others. (1997). SODIS- an emerging water treatment process. AQUA(OXFORD), 46(3), 127–137.

Spuhler, D., Andrés Rengifo-Herrera, J., and Pulgarin, C. (2010). The effect of Fe2+, Fe3+, H_2O_2 and the photo-Fenton reagent at near neutral pH on the solar disinfection (SODIS) at low temperatures of water containing Escherichia coli K12. Applied Catalysis B: Environmental, 96(1–2), 126–141. https://doi.org/10.1016/j.apcatb.2010.02.010

Ssemakalu, C. C., Ubomba-Jaswa, E., Motaung, K. S., and Pillay, M. (2015). The effect of solar irradiated Vibrio cholerae on the secretion of pro-inflammatory cytokines and chemokines by the JAWS II dendritic cell line in vitro. PLoS ONE, 10(6), e0130190. https://doi.org/10.1371/journal.pone.0130190

Ssemakalu, C. C., Ulaszewska, M., Elias, S., and Spencer, A. J. (2021). Solar inactivated Salmonella Typhimurium induces an immune response in BALB/c mice. Heliyon, 7(1), e05903. https://doi.org/10.1016/j.heliyon.2021.e05903

Stewart, C. P., Dewey, K. G., Lin, A., Pickering, A. J., Byrd, K. A., Jannat, K., Ali, S., Rao, G., Dentz, H. N., Kiprotich, M., Arnold, C. D., Arnold, B. F., Allen, L. H., Shahab-Ferdows, S., Ercumen, A., Grembi, J. A., Naser, A. M., Rahman, M., Unicomb, L., … Null, C. (2019). Effects of lipid-based nutrient supplements and infant and young child feeding counseling with or without improved water, sanitation, and hygiene (WASH) on anemia and micronutrient status: results from 2 cluster-randomized trials in Kenya and Bangladesh. The American Journal of Clinical Nutrition, 109(1), 148–164. https://doi.org/10.1093/AJCN/NQY239

Suárez, E., Pérez, C. M., Rivera, R., and Mart\'\inez, M. N. (2017). Applications of regression models in epidemiology. John Wiley \and Sons.

Tamas, A., Tobias, R., and Mosler, H. J. (2009). Promotion of solar water disinfection: comparing the effectiveness of different strategies in a longitudinal field study in Bolivia. Health Communication, 24(8), 711–722. https://doi.org/10.1080/10410230903264022

World Bank. (2018). Bangladesh: Access to Clean Water Will Reduce Poverty Faster. https://www.worldbank.org/en/news/press-release/2018/10/11/bangladesh-access-to-clean-water-will-reduce-poverty-faster

Thomann, R. v, and Mueller, J. A. (1987). Principles of surface water quality modeling and control. Harper \and Row Publishers.

Touati, D., Jacques, M., Tardat, B., Bouchard, L., and Despied, S. (1995). Lethal oxidative damage and mutagenesis are generated by iron in Δfur mutants of Escherichia coli: Protective role of superoxide dismutase. Journal of Bacteriology, 177(9), 2305–2314. https://doi.org/10.1128/jb.177.9.2305-2314.1995

Ubomba-Jaswa, E., Navntoft, C., Polo-López, M. I., Fernandez-Ibáñez, P., and McGuigan, K. G. (2009). Solar disinfection of drinking water (SODIS): an investigation of the effect of UV-A dose on inactivation efficiency. Photochemical and Photobiological Sciences 2009 8:5, 8(5), 587–595. https://doi.org/10.1039/B816593A

Uhl, L., Gerstel, A., Chabalier, M., and Dukan, S. (2015). Hydrogen peroxide induced cell death: One or two modes of action? Heliyon, 1(4), e00049.

UN. (2016). Water and Sanitation - United Nations Sustainable Development. Sustainable

Development Goals. https://www.un.org/sustainabledevelopment/water-and-sanitation/

UN. (2017). United Nations sustainable development agenda. United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/development-agenda-retired/%0Ahttp://www.un.org/sustainabledevelopment/development-agenda/

UN. (2022). Population | United Nations. https://www.un.org/en/global-issues/population

UNICEF, (2005). Desinfección Solar del Agua. https://www.sodis.ch/methode/anwendung/ausbildungsmaterial/index

UNICEF. (2018). Drinking Water Quality in Bangladesh: Meeting the SDG 6.1 for Safely Managed Drinking Water: Challenges, Evidence and Priority Recommendations. 1–8.

UNICEF. (2021). Billions of people will lack access to safe water, sanitation and hygiene in 2030 unless progress quadruples – warn WHO, UNICEF. https://www.unicef.org/bangladesh/en/press-releases/billions-people-will-lack-access-safe-water-sanitation-and-hygiene-2030-unless

UNICEF. Water | UNICEF. Retrieved February 19, 2023, from https://www.unicef.org/wash/water

United Nations Environment Programme. (2021). Globally, 3 billion people at health risk due to scarce data on water quality. United Nations. https://www.unep.org/news-and-stories/story/globally-3-billion-people-health-risk-due-scarce-data-water-quality

van Boekel, M. A. J. S. (2002). On the use of the Weibull model to describe thermal inactivation of microbial vegetative cells. International Journal of Food Microbiology, 74(1–2), 139–159. https://doi.org/10.1016/S0168-1605(01)00742-5

Venkatadri, R., and Peters, R. W. (1993). Chemical oxidation technologies: Ultraviolet light/hydrogen peroxide, Fenton's reagent, and titanium dioxide-assisted photocatalysis. Hazardous Waste and Hazardous Materials, 10(2), 107–149. https://doi.org/10.1089/hwm.1993.10.107

Vidal, A., and Díaz, A. I. (2000). High-Performance, Low-Cost Solar Collectors for Disinfection of Contaminated Water. Water Environment Research, 72(3), 271–276. https://doi.org/10.2175/106143000X137473

Vidal, A., Díaz, A. I., el Hraiki, A., Romero, M., Muguruza, I., Senhaji, F., and González, J. (1999). Solar photocatalysis for detoxification and disinfection of contaminated water: pilot plant studies. Catalysis Today, 54(2–3), 283–290. https://doi.org/10.1016/S0920-5861(99)00189-3

Villar-Navarro, E., Levchuk, I., Rueda-Márquez, J. J., and Manzano, M. (2019). Combination of solar disinfection (SODIS) with H_2O_2 for enhanced disinfection of marine aquaculture effluents. Solar Energy, 177, 144–154. https://doi.org/10.1016/J.SOLENER.2018.11.018

Vivar, M., and Fuentes, M. (2016). Using solar disinfected water: On the bacterial regrowth over 1-week of water usage including direct intake after sun exposure and long-term dark storage. Solar Energy, 131, 138–148. https://doi.org/10.1016/j.solener.2016.02.044

Vivar, M., Fuentes, M., Castro, J., and García-Pacheco, R. (2015). Effect of common rooftop materials as support base for solar disinfection (SODIS) in rural areas under temperate climates. Solar Energy, 115, 204–216. https://doi.org/10.1016/j.solener.2015.02.040

Vivar, M., Fuentes, M., García-Pacheco, R., and de Bustamante, I. (2013). Clean water photovoltaic sensor for solar disinfection in developing countries. Solar Energy Materials and Solar Cells, 117, 549–563. https://doi.org/10.1016/j.solmat.2013.07.021

Vivar, M., Pichel, N., and Fuentes, M. (2017). Solar disinfection of natural river water with low microbiological content (10–103CFU/100 ml) and evaluation of the thermal contribution to water purification. Solar Energy, 141, 1–10. https://doi.org/10.1016/j.solener.2016.11.019

Wang, M., Ateia, M., Awfa, D., and Yoshimura, C. (2021). Regrowth of bacteria after light-based disinfection — What we know and where we go from here. Chemosphere, 268, 128850. https://doi.org/10.1016/j.chemosphere.2020.128850

Waste, S., Luzi, S., Tobler, M., Suter, F., and Meierhofer, R. (2016). SODIS manual (Issue January 2002).

Water (2022). Bangladesh’s Water Crisis - Bangladesh’s Water In 2022 | Water.org. Water Organization. Retrieved September 27, 2022, from https://water.org/our-impact/where-we-work/bangladesh/

Wegelin, M. (2006). Training manual for SODIS Promotion. Lions Club, 39.

Wegelin, M., Canonica, S., Alder, C., Marazuela, D., Suter, M. J. F., Bucheli, T. D., Haefliger, O. P., Zenobi, R., McGuigan, K. G., Kelly, M. T., Ibrahim, P., and Larroque, M. (2001). Does sunlight change the material and content of polyethylene terephthalate (pet) bottles? Journal of Water Supply: Research and Technology - AQUA, 50(3), 125–133. https://doi.org/10.2166/aqua.2001.0012

Wegelin, M., Canonica, S., Mechsner, K., Fleischmann, T., Pesaro, F., and Metzler, A. (1994). Solar water disinfection: scope of the process and analysis of radiation experiments. Aqua, 43(4), 154–169.

WHO. (1987). Guidelines for drinking-water quality, volume 2: Health criteria and other supporting information. In Science of The Total Environment (2nd ed, Vol. 61, p. 274). World Health Organization. https://doi.org/10.1016/0048-9697(87)90388-3

WHO. (2004). Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization; 2022. World Health Organization, 21(6), 3–6.

WHO. (2011). Evaluating household water treatment options : Health-based targets and microbiological performance specifications. World Health Organization.

WHO. (2016). Results of round I of the WHO international scheme to evaluate household water treatment technologies. World Health Organization, 64. https://apps.who.int/iris/handle/10665/204284

WHO. (2019). Progress on drinking water, sanitation and hygiene 2000–2017. Unicef. https://www.unicef.org/reports/progress-on-drinking-water-sanitation-and-hygiene-2019

WHO. (2022a). Fact sheets on Drinking-water. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/drinking-water

WHO. (2022b). Guidelines for drinking-water quality 4th Edition (Vol. 33, Issue 33).

WHO/UNICEF. (2012). A toolkit for monitoring And evaluating household water treatment And safe storage programmes.

World Bank. (2020). Download solar resource maps and GIS data for 200+ countries and regions. © 2020 The World Bank, Source: Global Solar Atlas 2.0, Solar Resource Data: Solargis. https://solargis.com/maps-and-gis-data/download/namibia

Yin, X. F., Shi, N., Meng, T., and Sun, Y. X. (2020). Evaluation of solar light inactivation on multidrug-resistant Escherichia coli CGMCC 1.1595. Water

Science and Technology: Water Supply, 20(6), 2216–2225. https://doi.org/10.2166/ws.2020.124

Yuegang, Z., and Jürg, H. (1992). Formation of Hydrogen Peroxide and Depletion of Oxalic Acid in Atmospheric Water by Photolysis of Iron(III)-Oxalato Complexes. Environmental Science and Technology, 26(5), 1014–1022. https://doi.org/10.1021/es00029a022

APPENDIX I: LITERATURE REVIEW

Table A 1 SODIS efficiency with respect to solar irradiance

Author	Irradiation type	Wavelength range reported	Dose	Intensity	Result (selected pathogens)	Remarks
Wegelin et al. 1994	Simulated sunlight	350-450nm	555 Wh/m2	111 W/m2	3- 4 LRV in five hours for E. coli and St. faecalis,	
Heaselgrave & Kilvington 2010	Simulated sunlight	Wavelength range not specified		150W/m2	E.coli: 5.7 log reduction after 4h	wavelength range unclear
Bosshard et al. 2009	Simulated and natural sunlight	350-450nm		various	E.coli: 1% survival at 1700kJ/m2	
Dejung et al. 2007)	Natural sunlight	UV-A (320-400nm)		UV: 16.9Wm2 (average day)	Minimum UV-A dosage for 3LRV bacteria, including E. coli: 60Wh/m2 (4h on average days)	Mean water temperature 44 degrees
Fisher et al. 2012)	Natural sunlight	UV-A (320-400nm)		73W/m2 (calculated)	3 log reduction of labgrown E.coli in 3h, 7h for wastewater-derived E.coli	
Reed 1997	Natural sunlight	Not specified: Full spectrum.		600-750W/m2 (full spectrum?)	6log inactivation in 3h aerobically similar	Temperature < 28 degrees
McGuigan et al. 1998	Simulated sunlight, 300-1020nm:		2900 KJ/m2	700 W/m2 (corresp. sunny weather) 400 W/m2 (corresp.	3 log inactivation, 2.5 log inactivation, 2 log inactivation	

				To partly cloudy weather) 100 W/m2 (corresp. to overcast conditions		
Lonnen et al. 2005	Simulated sunlight	300-400nm		200W/m2	E.coli: 5.5 log inactivation in 2.5h	
Berney et al. 2006	Natural sunlight	350-450nm	2400 KJ/m2 in 6 -7h		E.coli: 3 log reduction requires 2000kJ/ m2	
Boyle et al. 2008	Natural sunlight	295-385 nm		Maximum noon intensity: >1000 W/m2 (full spectrum)	Inactivating 2 log E.coli takes 125 kJ/m2 (295385 nm). 4-log: Y. enterocolitica takes 150 minutes longer than enteropathogenic E. coli.	
Kehoe et al. 2001	Natural sunlight	300-20000nm			Full inactivation at 4-5 Mj(m2	High water temperature!
(Marques et al., 2013)	Natural sunlight	360-380nm		685.6 W/m2	50°C water inactivates 99.9% of E.coli in 3 hours.	High water temperature
(Kalt et al., 2014)	Natural sunlight	315-400 nm		24-36 W/m2 UVA	34 L of water treated for 4 hours reduces E.coli by 4 logs.	
(Giannakis et al., 2015)	Laboratory simulated intensity			500-1600 W/m2	4 log reduction simulation is done.	
Karim et al., 2021	Natural Sunlight			Monsoon: 491-535 Winter: 356	Different seasons and durations achieve 4 log reduction.	

Table A 2 Different LRVs according to global standards (Andrew et al., 2012)

No.	Standard	LRV	Implementation	Remarks
1.	US EPA Guide Standard-1987	Bacteria: 6 Virus: 4 Cyst: 3	Multiple technologies; murky water conditions	It's a pioneering and well-known guide standard, although it's open to interpretation.
2.	Israel SI 1505 Part 1, Part 2	Bacteria: 7 Virus: N/A Cyst: N/A	Covers filtration, UV, and RO systems for clean, nonturbid water.	
3.	Japan JIS 3835	Bacteria: report results only Virus: N/A Cyst: N/A	Covers membrane filters, but not turbid water.	A membrane filter rating test.
4.	Mexico NOMISO- SSA	Bacteria: 4/1.3 Virus: N/A Cyst: N/A	Covers just clean-water applications, not turbidity reduction.	4-log E. coli and 1.3-log aerobic bacteria decrease.
5.	Australia/New Zealand AS/NZS 4348	Bacteria: 6 Virus: 4 Cyst: 3	Covers several technologies, including turbid water.	EPA Guide Standard-influenced.
6.	Brazil ABNT NBR 14908	Bacteria: 2 Virus: N/A Cyst: N/A	Covers plumbed-in filtering systems, but not turbid water.	
7.	Brazil ABNT NBR 15176	Bacteria: 2 Virus: N/A Cyst: N/A	Gravity-fed filtration devices, clean water exclusively, no turbidity	
8.	Venezuela COVENIN 3377	Bacteria: claims verification only Virus: N/A Cyst: N/A	Covers non-ceramic filtration and ozonation systems, but not turbid water.	Verifies assertions without pass/fail criteria.
9.	Venezuela COVENIN 2840	Bacteria: claims verification only	Ceramic filtration systems, clean water only, no turbidity.	Only verifies claims; no pass/fail criterion.

		Virus: N/A Cyst: N/A		
10.	California Guidelines 2004	Bacteria: 6 Virus: 4 Cyst: 3.3	Covers several technologies, including turbid water.	EPA Guide Standard-influenced
11.	WQA ORD0901	Bacteria: 3 Virus: 3 Cyst: N/A	Gravity-fed filtration devices for pure, nonturbid water.	Developed nations-focused
12.	Proposed supplemental standard NSF/ANSI 244-3	Bacteria: 6 Virus: 4 Cyst: 3.3	Mechanical filtering systems, clean water exclusively, not turbid.	EPA Guide Standard-influenced. Certification for filtration systems that can prevent boil-water advisories.
13.	WHO HWT Guidelines 2011/ NSF P415	Highly protective Bacteria: 4 Virus: 5 Cyst: 4 Protective Bacteria: 2 Virus: 3 Cyst: 2	Covers several technologies, including turbid water.	EPA Guide Standard-influenced Designed for developing country local governments. WHO HWT Guidelines provide test methodology recommendations, but aren't prescriptive. NSF P415 employs NSF P231 and WHO HWT log reductions to make claims.

APPENDIX II: SODIS PERFORMANCE IN LABORATORY

EXPERIMENTS

Table A 3 Initial physicochemical characteristics of TW 1 in bottle containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June- October, 2022)	pH	7.92	8.70	8.34	0.19	0.04
	DO (mg/l)	7.18	9.45	8.11	0.66	0.47
	EC (µS/cm)	326.00	606.00	409.95	73.84	5841.86
	Turbidity (NTU)	35.10	57.33	46.18	6.52	45.57
	Temperature (°C)	26.20	32.00	28.95	1.45	2.25
Winter (November- February, 2023)	pH	7.56	8.32	7.95	0.22	0.05
	DO (mg/l)	7.12	8.25	7.78	0.31	0.11
	EC (µS/cm)	314.00	543.00	397.53	62.06	4126.55
	Turbidity (NTU)	1.75	12.98	3.65	2.59	7.21
	Temperature (°C)	19.20	28.10	25.69	2.55	6.97
Sample size (N) = 60						

Table A 4 Final physicochemical characteristics of TW 1 in bottle containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June- October, 2022)	pH	6.77	8.48	7.81	0.42	0.18
	DO (mg/l)	6.12	8.45	7.25	0.58	0.34
	EC (µS/cm)	279.00	885.00	770.07	84.59	7235.50

	Turbidity (NTU)	0.38	4.54	2.50	1.22	1.51
	Temperature (°C)	26.90	52.70	38.37	5.40	29.49
Winter (November-February, 2023)	pH	7.41	8.34	7.90	0.23	0.05
	DO (mg/l)	6.14	8.12	7.25	0.42	0.18
	EC (µS/cm)	687.00	898.00	796.63	51.51	2682.80
	Turbidity (NTU)	0.68	4.12	2.22	0.77	0.59
	Temperature (°C)	23.50	51.20	40.16	4.82	23.54
Sample size (N) = 60						

Table A 5 Initial physicochemical characteristics of TW 2 in bottle containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June-October, 2022)	pH	7.92	8.48	8.32	0.16	0.03
	DO (mg/l)	7.18	9.45	8.11	0.66	0.47
	EC (µS/cm)	326.00	606.00	409.95	73.84	5841.86
	Turbidity (NTU)	35.10	57.33	46.18	6.52	45.57
	Temperature (°C)	26.20	32.00	28.95	1.45	2.25
Winter (November-February, 2023)	pH	8.06	8.47	8.31	0.11	0.01
	DO (mg/l)	7.98	8.67	8.35	0.19	0.04
	EC (µS/cm)	337.00	575.00	416.33	68.48	5024.95
	Turbidity (NTU)	32.50	56.00	41.55	5.97	38.22
	Temperature (°C)	19.20	28.10	25.69	2.55	6.97

Sample size (N) = 60

Table A 6 Final physicochemical characteristics of TW 2 in bottle containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June- October, 2022)	pH	6.83	8.46	7.92	0.44	0.19
	DO (mg/l)	5.78	9.26	7.60	0.66	0.45
	EC (µS/cm)	511.54	955.00	785.00	69.06	4822.99
	Turbidity (NTU)	11.70	51.23	37.30	8.89	79.97
	Temperature (°C)	26.90	52.70	38.41	5.38	29.23
Winter (November- February, 2023)	pH	8.00	8.45	8.25	0.09	0.01
	DO (mg/l)	6.78	8.54	7.84	0.36	0.13
	EC (µS/cm)	698.00	896.00	808.69	51.10	2640.22
	Turbidity (NTU)	18.60	51.20	34.08	7.10	50.99
	Temperature (°C)	23.50	51.20	40.16	4.82	23.54
Sample size (N) = 60						

Table A 7 Initial physicochemical characteristics of TW 1 in plastic bag containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June- October, 2022)	pH	7.37	8.45	8.15	0.27	0.08
	DO (mg/l)	6.98	8.21	7.52	0.42	0.19
	EC (µS/cm)	312.00	584.00	380.73	73.90	5851.78

	Turbidity (NTU)	1.68	4.24	2.97	0.73	0.57
	Temperature (°C)	27.60	32.00	29.26	1.21	1.58
Winter (November-February, 2023)	pH	7.04	8.42	7.92	0.31	0.10
	DO (mg/l)	6.99	8.13	7.68	0.36	0.14
	EC (µS/cm)	341.00	684.00	454.13	91.07	8885.98
	Turbidity (NTU)	1.78	4.65	3.52	0.75	0.61
	Temperature (°C)	19.20	29.20	25.76	2.63	7.43
Sample size (N) = 60						

Table A 8 Final physicochemical characteristics of TW 1 in plastic bag containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June-October, 2022)	pH	7.21	8.83	8.11	0.34	0.12
	DO (mg/l)	6.25	8.04	7.03	0.39	0.15
	EC (µS/cm)	582.00	862.00	742.77	71.33	5144.92
	Turbidity (NTU)	0.25	4.42	2.48	0.97	0.95
	Temperature (°C)	31.90	52.70	38.27	4.14	17.32
Winter (November-February, 2023)	pH	7.02	8.45	7.92	0.31	0.10
	DO (mg/l)	6.09	8.03	7.11	0.44	0.19
	EC (µS/cm)	572.00	893.00	772.73	65.67	4360.69
	Turbidity (NTU)	0.99	4.24	2.69	0.87	0.76
	Temperature	23.50	51.20	40.16	4.82	23.54

	(°C)					
Sample size (N) = 60						

Table A 9 Initial physicochemical characteristics of TW 2 in plastic bag containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
Monsoon (June-October, 2022)	pH	7.90	8.70	8.32	0.22	0.08
	DO (mg/l)	7.28	8.47	7.87	0.31	0.19
	EC (µS/cm)	321.00	594.00	397.07	70.49	5851.78
	Turbidity (NTU)	35.00	65.40	46.05	8.45	0.57
	Temperature (°C)	27.60	32.00	29.31	1.18	1.58
Winter (November-February, 2023)	pH	7.92	8.48	8.27	0.16	0.03
	DO (mg/l)	7.47	8.47	8.21	0.26	0.07
	EC (µS/cm)	57.94	600.00	422.13	119.50	15301.53
	Turbidity (NTU)	30.78	69.40	46.50	9.61	98.95
	Temperature (°C)	19.20	29.20	25.76	2.63	7.43
Sample size (N) = 60						

Table A 10 Final physicochemical characteristics of TW 2 in plastic bag containers

Season	Parameters	Minimum	Maximum	Average	Standard Deviation	Variance
	pH	7.08	8.87	8.17	0.31	0.10
Monsoon (June-October, 2022)	DO (mg/l)	6.40	8.23	7.24	0.40	0.17
	EC (µS/cm)	529.00	872.00	751.24	70.63	5044.93
	Turbidity (NTU)	22.00	56.60	36.79	7.08	50.65
	Temperature (°C)	31.90	52.70	38.32	4.10	17.03
Winter (November-February, 2023)	pH	6.70	8.80	8.22	0.23	0.05
	DO (mg/l)	6.40	8.33	7.50	0.52	0.27
	EC (µS/cm)	57.95	896.00	781.08	105.24	11200.51
	Turbidity (NTU)	17.89	58.60	36.21	8.54	73.83
	Temperature (°C)	23.50	51.20	40.16	4.82	23.54
Sample size (N) = 60						

Table A 11 Plastic Bag E.coli test outcomes of both seasons

Monsoon Season				**Winter Season**			
TW-1		**TW-2**		**TW-1**		**TW-2**	
Serial (hour)	**E.coli (CFU/100 ml)**	**Serial (hour)**	**E.coli (CFU/100 ml)**	**Serial (hour)**	**E.coli (CFU/100 ml)**	**Serial (hour)**	**E.coli (CFU/100 ml)**
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000

1	80	1	170	1	3210	1	3950
2	20	2	130	2	630	2	970
3	10	3	30	3	30	3	150
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	500	1	750	Initial	2470	Initial	3210
2	150	2	220	1	430	1	780
3	10	3	120	2	0	2	0
4	0	4	30	3	0	3	0
5	0	5	0	4	0	4	0
6	0	6	0	5	0	5	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	800	1	1100	6	2700	6	4260
2	150	2	330	Initial	270	Initial	980
3	20	3	70	1	0	1	10
4	0	4	0	2	0	2	0
5	0	5	0	3	0	3	0
6	0	6	0	4	0	4	0

Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	700	1	1030	5	2970	5	3780
2	230	2	390	6	1840	6	2010
3	0	3	0	Initial	530	Initial	930
4	0	4	0	1	70	1	250
5	0	5	0	2	0	2	0
6	0	6	0	3	0	3	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	500	1	870	4	1780	4	2980
2	220	2	310	5	670	5	1540
3	0	3	0	6	30	6	340
4	0	4	0	Initial	0	Initial	0

5	0	5	0	1	0	1	0
6	0	6	0	2	0	2	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	2500	1	3110	3	1590	3	2120
2	790	2	1250	4	350	4	1020
3	430	3	770	5	0	5	150
4	10	4	50	6	0	6	0
5	0	5	0	Initial	0	Initial	0
6	0	6	0	1	0	1	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	2980	1	4390	2	1690	2	2410
2	1650	2	2110	3	670	3	1840
3	780	3	980	4	40	4	170
4	70	4	130	5	0	5	0
5	0	5	0	6	0	6	0
6	0	6	0	Initial	0	Initial	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	2330	1	3950	1	1450	1	1890
2	850	2	1530	2	390	2	670
3	200	3	410	3	0	3	30
4	0	4	10	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	2450	1	3200	Initial	1870	Initial	2450
2	770	2	1670	1	20	1	950
3	50	3	210	2	0	2	130
4	0	4	0	3	0	3	0
5	0	5	0	4	0	4	0
6	0	6	0	5	0	5	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1370	1	2780	6	1430	6	1760
2	410	2	890	Initial	310	Initial	470

3	10	3	30	1	0	1	0
4	0	4	0	2	0	2	0
5	0	5	0	3	0	3	0
6	0	6	0	4	0	4	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	870	1	1050	5	1370	5	1890
2	90	2	230	6	230	6	710
3	0	3	0	Initial	0	Initial	10
4	0	4	0	1	0	1	0
5	0	5	0	2	0	2	0
6	0	6	0	3	0	3	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	710	1	1150	4	1190	4	1780
2	30	2	190	5	370	5	470
3	0	3	0	6	0	6	0
4	0	4	0	Initial	0	Initial	0
5	0	5	0	1	0	1	0
6	0	6	0	2	0	2	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	780	1	990	3	2300	3	3450
2	20	2	70	4	940	4	1430
3	0	3	0	5	110	5	370
4	0	4	0	6	0	6	0
5	0	5	0	Initial	0	Initial	0
6	0	6	0	1	0	1	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	730	1	960	2	6990	2	7010
2	10	2	90	3	5450	3	5990
3	0	3	0	4	4670	4	3450
4	0	4	0	5	1560	5	1890
5	0	5	0	6	340	6	510
6	0	6	0	Initial	0	Initial	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000

1	330	1	510	1	1550	1	1890
2	0	2	0	2	230	2	370
3	0	3	0	3	0	3	0
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0

Table A 12 PET bottle E.coli test outcomes of both seasons

Monsoon Season				**Winter Season**			
TW-1		**TW-2**		**TW-1**		**TW-2**	
Serial (hour)	**E.coli (CFU/100 ml)**	**Serial (hour)**	**E.coli (CFU/100 ml)**	**Serial (hour)**	**E.coli (CFU/100 ml)**	**Serial (hour)**	**E.coli (CFU/100 ml)**
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1120	1	1350	1	3670	1	4270
2	120	2	320	2	1150	2	2010
3	30	3	80	3	170	3	470
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	930	1	1480	1	3170	1	3990
2	270	2	640	2	790	2	980
3	30	3	150	3	0	3	0
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1780	1	2190	1	3260	1	5670
2	480	2	760	2	70	2	1230

3	10	3	90	3	0	3	90
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	3590	1	4980	1	3200	1	4200
2	2130	2	3230	2	2310	2	3120
3	1010	3	2320	3	560	3	2010
4	320	4	750	4	120	4	670
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1100	1	1780	1	2120	1	2870
2	390	2	770	2	970	2	1320
3	10	3	130	3	110	3	410
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1450	1	1980	1	1820	1	1990
2	310	2	670	2	760	2	920
3	0	3	0	3	80	3	370
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1100	1	1790	1	201	1	2890
2	170	2	310	2	85	2	1160
3	0	3	0	3	17	3	420
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0

6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	870	1	1450	1	1770	1	1920
2	90	2	210	2	610	2	470
3	0	3	0	3	0	3	0
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	980	1	4670	1	1570	1	1900
2	270	2	2230	2	460	2	730
3	0	3	700	3	0	3	100
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1360	1	1890	1	1780	1	1930
2	130	2	310	2	590	2	610
3	0	3	0	3	0	3	50
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	980	1	1370	1	1719	1	2167
2	190	2	630	2	163	2	193
3	0	3	50	3	0	3	0
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1010	1	1730	1	1890	1	2130
2	390	2	730	2	530	2	890
3	0	3	110	3	10	3	60

4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	555	1	870	1	3460	1	4010
2	10	2	20	2	1450	2	2310
3	0	3	0	3	370	3	1010
4	0	4	0	4	0	4	430
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	770	1	1070	1	1990	1	2470
2	30	2	190	2	430	2	750
3	0	3	0	3	0	3	0
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0
Initial	50000000	Initial	50000000	Initial	50000000	Initial	50000000
1	1570	1	2140	1	2330	1	2570
2	52	2	1430	2	760	2	860
3	5	3	170	3	10	3	50
4	0	4	0	4	0	4	0
5	0	5	0	5	0	5	0
6	0	6	0	6	0	6	0

APPENDIX III: SODIS PERFORMANCE IN FIELD EXPERIMENTS

Table A 13 SODIS with H_2O_2 post-physicochemical parameters outcome

Location	Source	Test waters	pH	DO	EC	Temperature of water	Turbidity	Solar irradiance	Temperature panel
Mirpur	Piped	S-1	8.49	2.99	378	38.5	6.67	550.37	45.45
Mirpur	piped	S-2	8.4	4.88	367	38.1	5.59	550.37	45.45
Mirpur	tubewell	S-3	8.3	3.12	357	38.2	3.27	550.37	45.45
Mirpur	piped	S-4	8.3	6.34	326	38.5	0.4	550.37	45.45
Mirpur	piped	H-1	8.36	6.81	398	38.4	3.14	550.37	45.45
Malibagh	piped	H-2	8.24	6.7	406	38.5	0.21	550.37	45.45
Uttara sector 4	piped	H-3	8.33	6.76	329	38	0.42	550.37	45.45
Bashundhora	piped	H-4	8.28	7.24	399	38.1	0.28	550.37	45.45
Mirpur	Piped	R-1	8.49	7.15	350	37.2	1.93	503.64	40.08
Mirpur	piped	R-2	8.4	6.87	344	37.1	2.37	503.64	40.08
Mirpur	tubewell	R-3	8.3	4.99	344	37.2	1.27	503.64	40.08
Uttara	piped	R-4	8.3	7.43	262	37.5	1.85	503.64	40.08

Table A 14 SODIS post-physicochemical parameters outcome

Location	Source	Test waters	pH	DO	EC	Temperature of water	Turbidity	Solar irradiance	Temperature panel
Mirpur	Piped	S-1	7.96	6.93	332	37.4	6.25	681.87	49.16
Mirpur	piped	S-2	7.54	6.72	353	37.2	5.48	681.87	49.16
Mirpur	tubewell	S-3	7.43	6.8	348	37.1	3.26	681.87	49.16
Mirpur	piped	S-4	7.49	6.27	251	37	0.35	681.87	49.16
Mirpur	piped	H-1	7.47	6.72	270	37.2	3.02	681.87	49.16
Malibagh	piped	H-2	7.37	6.39	389	37.3	0.16	681.87	49.16
Uttara sector 4	piped	H-3	7.48	6.75	274	37.1	0.35	681.87	49.16
Bashundhora	piped	H-4	7.43	6.76	261	37.4	0.22	681.87	49.16
Mirpur	Piped	R-1	8.2	7.15	350	37.2	1.93	595.72	43.11

Mirpur	piped	R-2	8.15	6.87	344	37.1	2.37	595.72	43.11
Mirpur	tubewell	R-3	8.11	4.99	344	37.2	1.27	595.72	43.11
Uttara	piped	R-4	8.16	7.43	262	37.5	1.85	595.72	43.11