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Microbiological Evaluation of Water Treated with Solvatten

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Abstract

The study evaluated the efficiency of caloric processing of water using Solvatten equipment for the inactivation of indicator microorganisms and *Salmonella* spp. This equipment uses solar irradiation and temperature to inactivate and eliminate microorganisms in the treated water. The experiment was divided into two phases: performing a water analysis and evaluating the efficacy of reducing indicator microorganisms and pathogens. A paired sample design with two levels, high and low inoculum, with five repetitions for indicators and three for pathogens was used. The statistical program SAS v 9.4 analyzed the data using a student's t-test with a significance level ($P < 0.05$). The dependent variables evaluated were the concentration of total aerobic plate count (APC), *Enterobacteriaceae* (ENT), Total Coliforms (CT), *E. coli* (EC), and *Salmonella* (SAL). The inactivation results were 98.77% for coliforms and *Escherichia coli*; and 99.90% for *Salmonella*, proving that Solvatten leads to a decrease in the populations of bacteria of interest from 2 to 4 log CFU/mL. The results suggest that communities with difficulty accessing potable water may use the Solvatten unit to reduce the risk of diseases caused by coliforms.

Keywords

Water analysis, total coliforms, *Escherichia coli*, inactivation, SODIS

1. Introduction

Water is a crucial resource for survival, necessary for a large part of the physiological activities of the human body and other anthropogenic activities such as agriculture and industry [1]. Although this resource is present in many places, a large number of people around the world still need access to drinking water. In 2020, around one in four people lacked a safely managed drinking water source in their homes, and almost half of the world's population did not have access to safely managed sanitation services [2]. Access to drinking water has always been a primary concern as one of the fundamental rights of human health throughout the world [3]. In many urban areas, municipal water treatment facilities provide households with clean water typically treated by conventional methods such as filtration, chlorination, and UV radiation, among others [4]. In rural communities, obtaining drinking water is an arduous task for families. Communities with economic difficulties do not have water treatment services or municipal aqueducts that supply water to their homes, so they must opt for home water treatment. In these cases, the same communities are forced to hydrate themselves with water from different sources, which can be a severe health risk since the water is often contaminated.

The ingestion of contaminated water can result in various diseases, mainly diarrheal episodes. Every year, half a million people die from preventable diarrheal diseases, especially in low- and middle-income countries [5]. The consequences of diarrhea extend beyond acute dehydration and electrolyte imbalance. It is also linked to malnutrition and long-term outcomes such as reduced school attendance and future earnings potential [6]. The pathogenic microorganisms that cause diarrhea, cholera, and fever are related to *Shigella sonnei*, *Salmonella* spp., and *E. coli* due to contamination of fecal

material in the water. Besides bacteria, viruses can cause Hepatitis A and Hepatitis E, and amoebae, *Cryptosporidium* sp., and *Giardia* sp. are the most common pathogenic protozoa in water [7].

In search of a solution to the problem of lack of access to drinking water and sanitation services, new technologies have been developed, and research has been carried out on possible equipment and materials that can be used to reduce the microbial load contained in the water. One of the processes of most significant interest today is solar disinfection (SODIS). Solar disinfection is a practical, sustainable, and affordable intervention used in many parts of the world where access to clean water is challenging and available solar radiation levels are high. This method consists of filling containers with contaminated water and exposing them to direct sunlight for at least six hours [5]. The SODIS process is highly effective against many waterborne species of bacteria, viruses, protozoa, fungi, and others [8].

Solvatten is a portable dispositive that combines water treatment (solar radiation) and a water heating system to inactivate microorganisms that cause diarrhea or other diseases [9]. The equipment has a black hue to absorb more sunlight and thus raise the temperature to inactivate microorganisms. It has dimensions of 49 × 36 × 13 cm, with the capacity to process 10,000 mL of water [10]. When pouring the water into the Solvatten equipment, it passes through a cloth filter which can be replaced by cloth garments, maintaining the economic stability of the users [9]. The entire assembly is designed to be durable and maintenance-free. However, when working with solar energy, the device depends on the climate in which it is implemented. In other words, planning its use and longer exposure time will be needed in seasons with high rainfall rates to ensure that the water meets all the quality requirements for user intake. Furthermore, it is friendly to people of all ages since it is designed so that everyone can understand when the water finishes its processing through indicators. The objective of this study was to evaluate the presence of indicator microorganisms and *Salmonella* spp. after the UV treatment and heat processing of water.

2. Methods

2.1 Study location

The research was carried out at the Zamorano Food Microbiology Laboratory at the Pan-American Agricultural School Zamorano, Francisco Morazán, Honduras. The experiment was carried out between September and December 2020 and part of April 2021.

2.2 Preparation of indicator groups inoculum

Fresh heifer feces were collected from the Zamorano dairy herd. Portions between 10 and 20 g of feces were diluted with 100 mL phosphate buffer solution. Direct sowing of the fecal mixture was used for high inoculum. Two decimal dilutions were made using a proportion of 10 mL of the stool mixture in 90 mL of buffer solution for the low inoculum. Each inoculum level was adjusted to 10,000 mL of chlorine-free water inside a sterile plastic bag to obtain 3 Log CFU/100 mL and 5 Log CFU/100 mL.

2.3 Salmonella spp. inoculum preparation

Salmonella enterica strain serotype Typhimurium ATCC 14028 was reactivated by streaking stock cultures (maintained at -80 °C) in Standard Plate Count Agar (PCA) and incubating at 35 °C for 24 h. An isolated colony was taken from the plate using an inoculation loop and placed in a tube containing 10 mL of Trypticase Soy Broth (TSB), incubating for 24 hours at 35 °C. The incubated broth was diluted with 100 mL of phosphate buffer solution, and this was used to prepare the high inoculum (6 Log CFU/g) mixing in 10,000 mL of chlorine-free water. For the low inoculum (4 logs CFU/mL), two decimal dilutions of the TSB tube were made after incubation with 90 ml of phosphate buffer solution and then brought to a volume of 10,000 mL with chlorine-free water.

2.4 Preparation of equipment and application of treatments

A cheesecloth filter was placed over the inlet hole of the Solvatten unit, and 10,000 mL of the inoculated water treatments were poured into the equipment. The equipment has two compartments that store 5,000 mL of water each. The equipment was sun exposed for a time range of 3 to 5 hours, waiting for the change in the unit indicator, meaning the end of the process. The dispositive has a switch at the top of the right-wing, composed of two symbols: sad face (red) and green face (smiling); red means that the water needs to be treated, and green when the process is finished (Figure 1). Counts were made before and after sun exposure. Counts after sun exposure were performed in duplicate, analyzing both sides of the

equipment. Additionally, the internal water temperatures and external equipment temperatures were taken from both sides of the Solvatten unit.

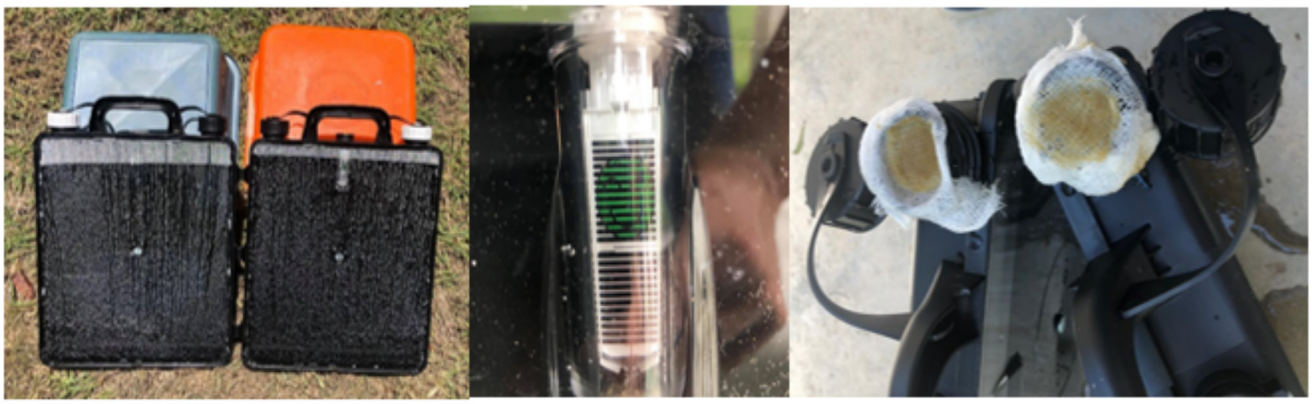

Figure 1. Preparation of the Solvatten equipment. A. Solvatten unit is a plastic case that unfolds like a book. B. Indicator Unit. C. Filling the mouth of the Solvatten with a cloth filter.

2.5 Enumeration of survival indicator groups

The levels of total aerobic plate count (APC), *Enterobacteriaceae* (ENT), total coliforms (TC), and *Escherichia coli* (EC) were analyzed. The APC and ENT counts were performed using the pour plate methodology established in the Bacteriological Analytical Manual and expressed in Log CFU/mL [11]. The TC and EC counts were processed by Membrane Filtration (MF), with the results described in log CFU/100 mL [12].

2.6 Enumeration of survival Salmonella

Counts of *Salmonella* spp. was determined by surface plating on xylose lysine deoxycholate agar (XLD), and the most probable number (MPN) technique using buffered peptone water (BPW) as enrichment broth, series of 5 tubes with 10 mL of undiluted sample. In addition, confirmation of MPN was made by biochemical tests on colonies recovered after streaking a drop of the contents of the BPW tubes onto XLD agar. The results were expressed in Log of CFU/mL and Log MPN/mL for the counts of the surface plate and MPN, respectively.

2.7 Experimental design

A paired sample design with high and low inoculum levels was used. For each level, the counts in the two treatments composed of before and after the processed water were evaluated. The dependent variables used were the concentration of APC, ENT, TC, EC, and *Salmonella* spp. Three independent replicates were performed for the *Salmonella* experiments and five independent replicates for the indicator group experiments. The data was analyzed in the statistical program SAS v 9.4 for the student's t-test with a significance level of 5% ($P < 0.05$).

3. Results

3.1 Survival of indicator microorganisms

After sun heat treatment of the water with the Solvatten unit with an average exposure time of 4.62 ± 0.86 hours, water reached an average temperature of 56.5 ± 5.0 °C. There was no significant difference between both sides of the equipment ($P=0.2065$). Samples with low inoculum, APC, and ENT count reductions of 2.8 and 1.2 log CFU/mL were obtained, respectively. A 2.8 and 2.9 Log CFU/100 mL decrease for TC and EC were demonstrated, respectively. Samples with high inoculum levels showed a 1.6 and 3.6 Log CFU/mL reduction for APC and ENT. The decrease of TC and EC was 3.6 logs CFU/ 100 mL and 4.3 logs CFU/ 100 mL, respectively (Table 1). Both inoculum levels show similar reduction efficiency in disinfecting more than 90% of all indicator microorganisms. In this study, there were no significant differences in the percentages of disinfection between high and low inoculum ($P>0.05$) (Table 2).

3.2 Salmonella survival

With an average exposure time of 6.18 ± 1.25 h, water temperatures of 50.33 ± 6.03 °C were reached for side A and 49.53 ± 4.51 °C for side B. Both temperatures did not show a significant difference (P=0.7084). No growth of *Salmonella* spp. was observed on the samples seeded directly on selective agar (detection limit of 100 CFU/mL). The pathogen was recovered after enrichment in BPW in the low and high inoculum samples. The high inoculum samples were all positive for *Salmonella* spp. after treatment with the Solvatten unit. Pathogen counts in samples with low inoculum began with an initial concentration of 4.5 ± 0.16 log CFU/mL, which decreased to -1.08 ± 0.44 cells /mL. In two of the three experiments, the low inoculum counts were >16 MPN/100 mL (Table 3).

Table 1. Counts of indicator groups in water contaminated and treated with Solvatten solar units.

Indicator group	High Inoculun		Low Inoculum	
	Before	After	Before	After
APC (Log CFU/mL)	4.23 ± 0.50	2.83 ± 0.27	3.82 ± 0.72	0.90 ± 0.47
ENT (Log CFU/mL)	3.92 ± 0.89	-0.27 ± 0.09	1.45 ± 0.46	-0.23 ± 0.14
TC (Log CFU/100 mL)	5.41 ± 0.87	1.72 ± 0.86	3.31 ± 0.31	0.52 ± 1.04
EC (Log CFU/100 mL)	5.08 ± 1.14	0.74 ± 1.14	3.28 ± 0.27	0.40 ± 1.08

Notes. APC: Aerobic Plate Count; ENT: *Enterobacteriaceae*; TC: Total Coliforms; EC: *Escherichia coli*

Table 2. Percentage reductions of indicator groups in contaminated water treated with Solvatten.

Inoculum level	Indicator group			
	APC ± SD (%)	ENT ± SD (%)	TC ± SD (%)	EC ± SD (%)
High	92.91 ± 11.75	99.99 ± 0.002	99.96 ± 0.06	99.94 ± 0.13
Low	99.90 ± 0.11	99.41 ± 1.320	99.31 ± 1.28	99.12 ± 1.76
P-value	0.2789	0.3474	0.2904	0.3327

Notes. SD: Standard Deviation. APC: Aerobic Plate Count. ENT: *Enterobacteriaceae*. TC: Total Coliform. EC: *Escherichia coli*.

Table 3. *Salmonella* survival in contaminated water treated with Solvatten solar equipment.

Inoculum level	Before Log CFU/mL	After Log CFU/mL	Confirmation MPN
High	5.41 ± 0.87	<2.0[⊕]	POSITIVE[+]
Low	4.50 ± 0.16	<2.0[⊕]	POSITIVE

Notes. [⊕]All samples were below the limit of quantification in the plate technique <100 CFU/mL.

[+] All samples were above the most probable number method limit of quantification of 2.2 at 16 MPN/100 mL.

4. Discussion

Similar results to those reported in this research have been published in studies of the efficiency of solar equipment for water treatment. Water samples from different locations exposed to the sun in PET bottles for up to 6 hours reached 99% disinfection of *E. coli* in the samples [8, 13, 14]. In another related study, Wegelin et al. [15] established that the temperature used by the SODIS method should range between 50 to 60 °C, which must be maintained for one hour for effective inactivation of microorganisms. The heating of the water is due to long-wave radiation (700 nm), infrared, which is absorbed by the liquid. Geographical aspects of the area should also be taken into consideration since the most favorable regions to apply solar disinfection are located between latitudes 15 °N and 35 °N, as well as 15 °S and 35 °S, which are

characterized by the more significant amount of solar radiation [16]. In the case of the geographic location of the Pan-American Agricultural School, it is located at latitude 14° 01' 46" N and longitude -87° 00' 00".

The nature of indicator microorganisms must be considered since they can generate resistance to the temperature and radiation barriers reached by the Solvatten unit. According to reduction percentages results, for both levels of inoculum, a lower percentage of reduction was seen for APC compared to the rest of the indicator microorganisms. This group of bacteria belongs to Gram-positive and negative, bacilli, cocci, and some spore-forming bacteria that might resist [3]. The results show that the APC counts had the lowest reduction percentage since this group is the largest. Some microorganisms can even generate resistance or enter latency when exposed to Solvatten temperatures. However, when found again in favorable conditions, such as incubation temperature (35 ± 2 °C) and nutrients from the culture media, these microorganisms can proliferate, explaining the reason for less inactivation compared to the rest of those that were evaluated. *Enterobacteriaceae* (ENT) are bacilli, Gram-negative, non-sporulated, facultative anaerobes with the ability to ferment carbohydrates without oxygen. It is worth mentioning that total coliforms and *E. coli* belong to this family of microorganisms.

López González [17] in his research evaluated samples from natural sources in Guatemala with average initial concentrations of 3.85 logs MPN/ 100 mL of total coliforms and 2.31 logs MPN/ 100 mL of *E. coli*, which were exposed to the sun for eight consecutive hours in 2,000-milliliter PET bottles. After processing, a 100% reduction was achieved in 15 (75%) of the 20 samples analyzed for *E. coli* and 13 (65%) of the 20 total coliform samples, which were evaluated by the Colilert Most Probable Number method. Lewis and Mak [18] reported, in their comparative research on the evaluation of total coliforms and *E. coli*, that the results between Membrane Filtration and Colilert agree at 98.5% for both methodologies. The decrease in solar energy transmission due to the thickness of the plastic used for processing must also be considered [19]. According to Lawrie et al. [20] and López González [17], solar disinfection occurring in plastic bags is easier to reach 50 °C than in plastic bottles because there is a more significant proportion between the exposed surface and the depth of water. A more substantial amount of liquid contained, approximately 10,000 mL of water, inside the Solvatten unit compared to 1,000 or 2,000 mL that can be collected inside the plastic bags or jars.

Wegelin et al. [15] concluded that a temperature of 58 °C is needed, which must be maintained for 60 minutes, for total disinfection of *Salmonella*. In the internal temperature obtained with the Solvatten unit, the values ranged from 41.3 °C to 57.3 °C, explaining the possible cause of partial disinfection of the analyzed samples of this microorganism. According to the research carried out by Walker et al. [21], *Salmonella* Typhimurium reductions of 3.5 and 5.5 logarithmic units were reported in solar disinfection of water in food-grade plastic bags. However, these results vary because they were evaluated at different times of the year in Connecticut, with more effective disinfection in the water during the late spring season. In the same way, Berney et al. [22] evaluated the efficacy of solar disinfection on pathogenic microorganisms in suspension in quartz glass, including *Salmonella* Typhimurium. These were exposed to temperatures within a range of 41-52 °C, obtaining reduction values of 5 logs CFU/mL at 50 °C after 4 hours of exposure.

One factor that must be considered for elaborating on solar disinfection devices is the material with which the equipment is made [19]. For example, Walker et al. [21] evaluated different materials in solar disinfection bags, comparing those that absorb and reflect light. As a result, it was shown that those bags made with metalized plastics had a better performance on *Salmonella* reduction, reducing 3.5 log units, compared to 1 log unit for the black plastic material to absorb light and increase the water temperature. Thus, improvements can be made on SODIS devices, specifically Solvatten, to achieve more significant microbiological inactivation.

To summarize, Solvatten's solar disinfection device did not achieve complete inactivation of microorganisms, both indicator and pathogenic. Therefore, the results of microbiological counts did not comply with the provisions of the WHO [23] since *E. coli* and total coliforms should not be detectable in any of the samples evaluated. However, the WHO also presents a health risk classification system when consuming water contaminated with coliforms, shown in CFU/100 mL, in which it is established that between 1-10 is low risk, 10-100 intermediate risk, 100-1000 high risk and >1000 very high risk. The results of the reduction of microorganisms show a decrease in the health risk, in which the inoculated water before processing was a very high risk. However, after treatment, it was an intermediate risk, suggesting that there will be a decrease in diarrheal diseases in communities that use the equipment correctly [24, 25].

5. Conclusion

Solvatten heat water treatment equipment can reduce an average of 98.77% of indicator microorganisms APC, ENT, TC, EC, and 99.9% *Salmonella*. These reductions mean a decrease in the risk of diseases caused by coliforms. After water processing, there were reductions of 3 logs of *Salmonella*. The results suggest that communities with difficulty accessing

potable water may use the Solvatten unit to reduce the risk of waters considered high risk. Before implementing this technology in rural communities, the water level of contamination must be known so that primary interventions (such as filtration and flocculation) can be applied before using the equipment. Additionally, it is crucial to train the population in the usage of the equipment, the work limitations of the equipment, and hygiene practices for properly handling and storing treated water.

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References

[1] Pooi CK, Ng HY. (2018). Review of low-cost point-of-use water treatment systems for developing communities. npj Clean Water. 1(1). doi:10.1038/s41545-018-0011-0.

[2] [WHO] World Health Organization, [UNICEF] United Nations Children's Fund. (2021). Billions of people will lack access to safe water, sanitation and hygiene in 2030 unless progress quadruples – warn WHO, UNICEF. New York, Geneva: [publisher unknown]; [accessed 2022 Oct 27]. https://www.unicef.org/press-releases/billions-people-will-lack-access-safe-water-sanitation-and-hygiene-2030-unless.

[3] Azamzam AA, Rafatullah M, Yahya EB, Ahmad MI, Lalung J, Alharthi S, Alosaimi AM, Hussein MA. (2021). Insights into Solar Disinfection Enhancements for Drinking Water Treatment Applications. Sustainability. 13(19):10570. doi:10.3390/su131910570.

[4] Cowie BE, Porley V, Robertson N. (2020). Solar Disinfection (SODIS) Provides a Much Underexploited Opportunity for Researchers in Photocatalytic Water Treatment (PWT). ACS Catal. 10(20):11779-11782. doi:10.1021/acscatal.0c03325.

[5] Polo-López MI, Martínez-García A, Abeledo-Lameiro MJ, H Gómez-Couso H, E Ares-Mazás E, Reboredo-Fernández A, Morse TD, Buck L, Lungu K, McGuigan KG, et al. (2019). Microbiological Evaluation of 5 L- and 20 L-Transparent Polypropylene Buckets for Solar Water Disinfection (SODIS). Molecules. 24(11). eng. doi:10.3390/molecules24112193.

[6] Pavlinac PB, Brander RL, Atlas HE, John-Stewart GC, Denno DM, Walson JL. (2018). Interventions to reduce post-acute consequences of diarrheal disease in children: a systematic review. BMC Public Health. 18(1):208. eng. doi:10.1186/s12889-018-5092-7.

[7] [CAWST] Centre for Affordable Water and Sanitation Technology. 2011. Introducción al tratamiento agua a nivel domiciliario. Alberta, Canada: [publisher unknown]; [updated 2012; accessed 2022 Sep 22]. https://sswm.info/sites/default/files/reference_attachments/CAWST%202011.%20Introducci%C3%B3n%20al%20tratamiento%20agua%20a%20nivel%20domiciliario.pdf.

[8] Karim MR, Khan MHRB, Akash MA-S-A, 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. doi:10.2166/washdev.2021.243.

[9] Hagström E, Lundström H. (2012). A field study in Kenya of isolation parameters to make water drinkable in the household water treatment unit SOLVATTEN [Thesis]. Uppsala: Uppsala Universitet. 38 p; [accessed 2023 Jan 18]. http://files.webb.uu.se/uploader/858/MFS-173hagstromlundstromminskadfil.pdf.

[10] Solvatten. (2019). Solvatten® - Solar Safe Water System, SSWS-10. [place unknown]: [publisher unknown]; [accessed 2020 Sep 22]. 7 p. https://www.engineeringforchange.org/wp-content/uploads/2015/08/Product-Specification-2019.pdf.

[11] Maturin L, Peeler JT. (2001). BAM Chapter 3: Aerobic Plate Count. In: Official methods of analysis of AOAC International. 8th ed. Rockville, Maryland: AOAC International; [accessed 2022 Oct 26]. https://www.fda.gov/food/laboratory-methods-food/bam-chapter-3-aerobic-plate-count.

[12] Baird RB, Eaton AD, Rice EW, Bridgewater L, editors. (2017). Standard methods for the examination of water and wastewater. 23rd ed. Washington, D.C.: American Public Health Association. ISBN: 978-0-87553-287-5.

[13] Ormaza Saldaña CO. (2011). Desinfección solar en el agua del río Tomebamba [Monography]. Cuenca, Ecuador: University of Cuenca Faculty of Engineering School of Civil Engineering. 61 p; [accessed 2022 Oct 26]. https://dspace.ucuenca.edu.ec/bitstream/123456789/744/1/ti872.pdf.

[14] Zaman S, Yousuf A, Begum A, Bari ML, Rabbani KS. (2019). Evaluation of adaptive low cost solar water pasteurization device for providing safe potable water in rural households. J Water Health. 17(2):274-286. eng. doi:10.2166/wh.2019.268.

[15] Wegelin M, Saladin M, Mercado A, Encalada M, Soto B, Medrano G, Altamirano O. (2005). Solar water disinfection: Application guide. 1st ed. Cochabamba, Bolivia: Sodis Foundation. 82 p. [accessed 2022 Oct 26]. https://www.bivica.org/files/agua-desinfeccion-solar.pdf.

[16] Luzi S, Tobler M, Suter F, Meierhofer R. (2016). SODIS Manual: Guidance on Solar Water Disinfection. Duebendorf, Switzerland: Eawag. ISBN: 978-3-906484-59-4; [accessed 2022 Oct 26]. https://www.sodis.ch/methode/anwendung/ausbildungsmaterial/dokumente_material/sodismanual_2016.pdf.

[17] López González RA. (2011). Application of the SODIS solar disinfection method in natural water sources used for human consumption in communities of San Juan Sacatepéquez, Guatemala [Thesis]. Guatemala: University of San Carlos of Guatemala; [accessed 2022 Oct 26]. https://biblioteca-farmacia.usac.edu.gt/Tesis/QB993.pdf.

[18] Lewis CM, Mak JL. (1989). Comparison of membrane filtration and Autoanalysis Colilert presence-absence techniques for analysis of total coliforms and Escherichia coli in drinking water samples. Appl Environ Microbiol. 55(12):3091-3094. eng. doi:10.1128/aem.55.12.3091-3094.1989.

[19] García-Gil Á, Pablos C, García-Muñoz RA, McGuigan KG, Marugán J. (2020). Material selection and prediction of solar irradiance in plastic devices for application of solar water disinfection (SODIS) to inactivate viruses, bacteria and protozoa. Sci Total Environ. 730:139126. eng. doi:10.1016/j.scitotenv.2020.139126.

[20] Lawrie K, Mills A, Figueredo-Fernández M, Gutiérrez-Alfaro S, Manzano M, Saladin M. (2015). UV dosimetry for solar water disinfection (SODIS) carried out in different plastic bottles and bags. Sensors and Actuators B: Chemical. 208:608-615. doi:10.1016/j.snb.2014.11.031.

[21] Walker DC, Len S-V, Sheehan B. (2004). Development and evaluation of a reflective solar disinfection pouch for treatment of drinking water. Appl Environ Microbiol. 70(4):2545-2550. eng. doi:10.1128/AEM.70.4.2545–2550.2004.

[22] Berney M, Weilenmann H-U, Simonetti A, Egli T. (2006). Efficacy of solar disinfection of Escherichia coli, Shigella flexneri, Salmonella Typhimurium and Vibrio cholerae. J Appl Microbiol. 101(4):828-836. eng. doi:10.1111/j.1365-2672.2006.02983.x.

[23] [WHO] World Health Organization. (1997). Guidelines for drinking-water quality. 2nd ed. Geneva: World Health Organization. 238 p. ISBN: 9241545038; [accessed 2022 Oct 27]. https://www.who.int/publications/i/item/9241545038.

[24] Rose A, Roy S, Abraham V, Holmgren G, George K, Balraj V, Abraham S, Muliyil J, Joseph A, Kang G. (2006). Solar disinfection of water for diarrhoeal prevention in southern India. Arch Dis Child. 91(2):139–141. eng. doi:10.1136/adc.2005.077867.

[25] Islam MA, Azad AK, Akber MA, Rahman M, Sadhu I. (2015). Effectiveness of solar disinfection (SODIS) in rural coastal Bangladesh. J Water Health. 13(4):1113-1122. eng. doi:10.2166/wh.2015.186.