RESEARCH ARTICLE

FACILE DISINFECTION OF RIVER AND POND WATER USING NATURAL SOLAR RADIATION AT SHOA ROBIT AND NEIGHBORING RURAL KEBELES.

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Manuscript Info

Abstract

In this study, disinfection of water using a simple and green approach using natural Solar Radiation Disinfection (SODIS) techniques has been investigated. The water samples in a colorless polyethylene plastic were irradiated with solar radiation. The reduction of Total Coliform (TC) using solar radiation further investigated by introducing aluminum foils and mirrors as activators for the sterilization of TC. The raw water samples were obtained from local municipal drinking water and ponds in *Shoa Robit* and the surrounding rural areas. The total coliform reduction potential of SODIS results 99.9 % decontamination at the end of six hours. Moreover, the results were showed that the disinfection process succeeded at the end of six hours using either of activators or not at *Shoa Robit* and neighboring rural kebeles. However, the relative disinfection efficiency varies with the following order; treatment using mirrors > aluminum foil > treatment without activators.

Introduction:-
During the last decades waterborne diseases have taken the world leading killer. There are 3.575 million deaths each year from water-related disease, and 98% of these occur in developing countries [1]. To overcome this adverse effect point-of-use (POU) water treatment technologies have received increasing attention as valuable tools for improving drinking water quality [2-4]. Chemical disinfection, membrane filters, thermal technologies, coagulation and solar water disinfection (SODIS) are common POU water treatment technologies. Among all SODIS due to low cost and ease of use have received a huge interest for disinfection microbes from polluted water. This simple point-of-use treatment can be utilized to create safe drinking water in rural areas of developing countries and in emergency situations (wars and natural disasters) [5]. It consists of exposing a bottle of biologically contaminated water to direct sunlight, allowing the ultraviolet (UV) component of the light to energize reactions in the water that kill or inactivate microorganisms [6-7].

The UV light that reaches the earth's surface is mainly in the UV-A and UV-B regions, which consist of the wavelengths from 280-315 nm and 315-340 nm, respectively. This part of the light is capable of disinfecting water. The 200 – 300 nm wavelengths can be absorbed by DNA and RNA, fusing thymine or uracil base pairs and causing mutations that inhibit reproduction [8]. Solar intensity varies with location, time of day, season, weather conditions, and many other factors. Average intensity levels in the areas near the equator get the most direct sunlight; it is generally recommended that SODIS be used with the latitude range from 35N to 35S [9]. Most of developing regions of the world lie in these latitudes, which is where low cost water treatment is most needed.

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However, the potential of natural solar radiation disinfection at different parameters are not fully defined. UV absorbing organics and turbidity are the sources of potential interference for SODIS technique. Besides, the dependence of SODIS on latitude, altitude, and geographic factors on disinfection potential has not been systematically documented. Therefore, in this paper we report a facile and enhanced disinfection of biological contaminated water using natural solar radiation. The enhanced disinfection efficiency of SODIS was investigated at different activation agents, including aluminum foil and mirror. pH and turbidity of water was also studied.

Materials and methods:-
Source of water samples:-
Shewa Robit is a town in north-central Ethiopia. Located in the *Semien Shewa* Zone of the Amhara Region, has a longitude and latitude of 10°06′N 39°59′E / 10.1°N 39.983°E with an elevation of 1280 meters above sea level. The water sample was collected from *Shoa-Robit* municipal water and surrounding rural kebeles (*Abay Atir* and *Ashale* ponds) two times during the period from April, 2012- May,2012, and Augest,2012 - September, 2012. A volume of 8 L of water was collected in sterile plastic bags. Samples were kept in ice box during transfer and processed after transportation at DBU Chemistry and Biology laboratories. Temperature of water was recorded immediately in the field, while pH, the conductivity, the alkalinity and coliform were sent to DBU.

Sampling procedure:-
The technique used for sampling from wells was according to the procedure described by WHO. Then water sample was divided into five groups (each 1.5 L) and then exposed to solar radiation on the roof (without activator), with mirror, and with aluminum foil at the research are for the period of 6 hours, but during this period and every each hour, water sample was taken from each group for culturing to estimate the reduction in the bacterial concentration due to exposure to sunlight. After arriving in the laboratory water samples were cultured on different media at a starting time (zero time), to estimate the bacterial counts of water samples.

pH analysis of the water:-
Measurement of pH is one of the most important and frequently used tests, as every phase of water and wastewater treatment and waste quality management is pH dependent. pH value is governed largely by the carbon dioxide/ bicarbonate/ carbonate equilibrium. The effect of pH on the chemical and biological properties of liquid makes its determination very important. Here it was measured by a pH meter (pH meter 340i/SET, WTW 82362 Weilhim).

Microbiological examination of water samples:-
Microbiological examinations were performed to determine the Total Coliform (TC). The original sample, 0.1 ml was directly pipetted into the surface of the prepared agar plates and distributed all over using a sterile L-shaped glass loop. The plates were incubated at 35 °C for 24 to 48 h. The colonies will form on the surface of the agar plate from both original and diluted samples were counted using Quebec Colony Counter and recorded as CFU/ml.

Statistical analysis of the efficient of various reflectors and sunlight only:-
The relative disinfection efficiency of SODIS method with mirror, aluminum foil, and without reflector as well as contact time was analyzed their significances by Analysis of Variance (ANOVA) model.

Result and Discussion:-
pH of water:-
pH of water   expresses the concentration of the acid or alkaline condition of a solution. It is one of the most important operational water quality parameters, the optimum pH required often being in the range 6.5–9.5. However, the drinking water use in *Shoa Robit* (pH ~ 7.4) and *Rasa kebeles* (pH~ 7.2-7.8) which is close resemble to the standard WHO water quality parameter [10].

Turbidity test:-
The water turbidity is main factor to SODIS water treatment method. If the water is very turbid, the effective of the method is reduced. It was used a facile Nuephelometric method to investigate the turbidity of water samples. The filled PET bottle must be placed on the top of the newspaper head line. Now one must look at the bottom of the bottle from the neck at the top and through the water. If the head line of the paper is readable, the water can be used. The turbidity of *Shoa Robit* municipal drinking water is much clear than *Rasa Kebeles* drinking waters. This High

level of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria and decrease the potential of solar radiation to disinfect microbes.

Microbe disinfection study:-
The impacts of natural solar radiation on the inactivation of bacterial coliform was investigated. The effect of mirror and aluminum foil compared with the absence of activator was tested as well as the duration of sunlight was tested.

The disinfection efficiency SODIS at various contact time in *Shoa Robit town:-*
The disinfection efficiency of natural solar radiation at different hours were investigated. At the end of one-hour disinfection efficiency of SODIS was recorded as shown in Table. 3.1

Table 3.1:- The total coliform concentration count at Shoa Robit at the end of one hour with mirror, aluminum foil and without activator.

Without Activator	With Mirror	With Aluminum Foil	Control
1750	1210	1400	5320
970	1200	1765	5340
1830	1300	1340	7670
1870	1600	1570	4780
1650	1700	1680	6540
1400	1340	1700	5900
7800	1700	1670	6230
1400	1900	1570	5800

The analysis of variance (ANOVA) at the end of one hour (Table. 3.1) has clearly indicated that the null hypothesis can be rejected for the statement "all treatments are the same"; the Fobs value is 24.24, which is much greater than the Fcrit. value, 2.95.

The analysis of variance (ANOVA) for time one hour

Source	df	SS	Mean square	F_{obs}	F_{crit} (3;0.05)
Treatment agents	3	106364446.1	35454815.36	24.2400801	2.95
Within treatments	28	40954271.88	1462652.567		
Total	31				

Table. 3.3:- The least significant difference (LSD)

Term	constant	Value
# of treatment	K	4
required # of tests	c=k(k-1)/2	6
overall level of significance	b	0.05
level of significance	α=b/c	0.00833333
mean square	MSD	1462652.57
average no. of sample size(n)		8
standard error for two means (s.e.)	$(2(MSE)/n)^{1/2}$	604.70087
t-static	$t_{28,0.01}$	2.467
LSD		1491.79705

The least significant difference (LSD) was also calculated as shown in Table 3.3. The number of treatment agents (k) was four. The number of required experiments (c) was six. To achieve an overall confidence interval of 95% (b), the experiments were performed at a significance level of 99% (α). To calculate the LSD, the standard error of the difference

LSD = s.e.($t_{28,0.01}$) = 1491.79705

Therefore, the averages TC concentrations (**Table 3.4**) for the bottles disinfected with mirror and other treatment as compared with control is larger than the LSD (1491). Hence, the treatment either of methods for one hour makes statically different output. But, there is no significant statically differences between the treatment methods with one hours.

Table 3.4:- Average TC concentration at the end of one hour

Treatment	Average coliform
Without activator	2333
With mirror	1493
With aluminum foil	1586
Control	5947

Besides, analysis of variance for the disinfection efficiency of SODIS at the end of six hours was calculated as shown Table 3.5. It shows that the null hypothesis cannot be rejected for the

Table 3.5:- The analysis of variance of different treatments at *Shoa Robit* at the end of six hours

Source	df	SS	Mean square	Fobs	Fcrit (2;0.05)
Treatments	2	16.08333	5.361111	0.494329	3.47
Within treatment	21	227.75	10.84524		
Total	23				

statement "all treatments are the same"; the Fobs value is 0.494, which is less than the Fcrit. value, 3.47.

Table. 3.6:- The least significant difference (LSD)

Term	constant	value
# Of treatment	K	4
Required # Of tests	$c=k(k-1)/2$	6
Overall level of	$b=$	0.05
significance level of significance	$\alpha=b/c$	0.008333
mean square	MSD	10.84524
average no. of sample size	n	8
standard error for two means	$s.e. = (2(MSE)/n)^{1/2}$	1.646605
t-stastic	$t_{21},0.01$	2.518
LSD		4.146153

The obtained LSD (**Table 3.6**) is **LSD = s.e.($t_{21,0.01}$) = 4.146.** The difference between the average coliform concentrations (**Table 3.7**)   for the bottles disinfected by solar radiation without activator and with activators including mirror and with aluminum foil is smaller than the LSD (4.15). Hence, the treatment either of methods (with mirror and with aluminum foil) as well as treatment without any activator did not bring statistical different at the end of six-hour period.

Table 3.7:- Average TC concentration at the end of one hour at *Ashal Kebele*

Treatment	Average coliform
Without activator	7
With mirror	5
With aluminum foil	6

In general, the relative disinfection efficiency of SODIS as a function of time as shown in **Figure 3.1**, the disinfection efficiency of natural solar radiation with increasing the contact time.
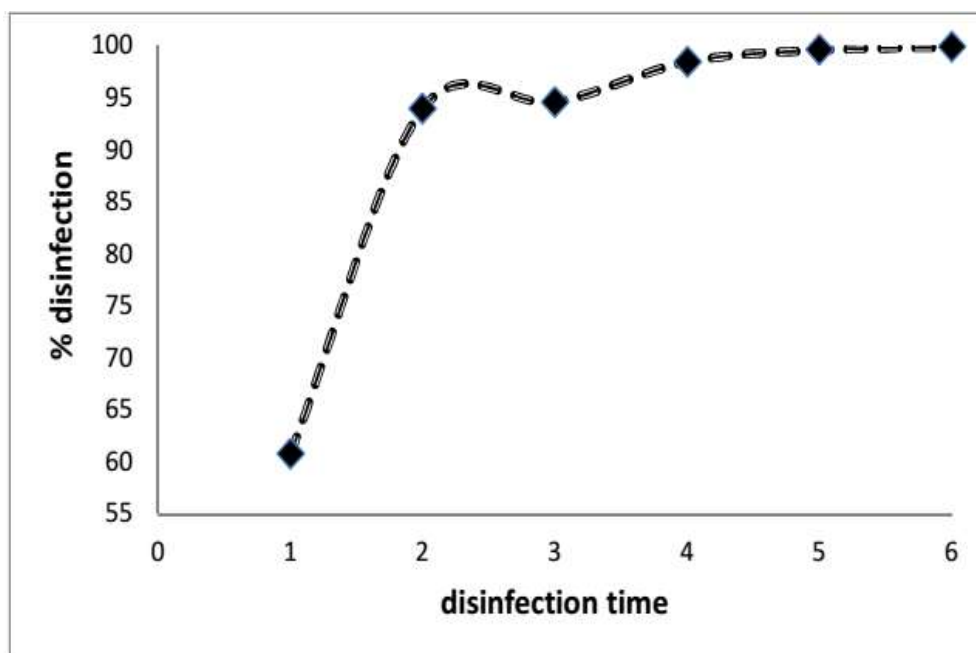
Figure 3. 1:- The disinfection efficiency of natural SODIS at Shoa Robit

The disinfection efficiency SODIS at various contact time at *Ashal kebele*:-
The disinfection efficiency of SODIS at the end of one hour is presented in Table 3.8. The analysis of variance (ANOVA) at the end of one hour was determined to check the significance in deference between SODIS treatment of water with and without activators. The results were shown that all SODIS treatment of water at different activators will bring different degree of disinfection at the end of one hour.

Similarly, the disinfection efficiency of SODIS was investigated at different hours. At the end of six hours, SODIS have strong efficiency to disinfect the microorganism. The table below shows the analysis of variance (ANOVA) for time six hours as shown in Table 3.9, ANOVA table at the end of six hours, the null hypothesis cannot be rejected for the statement "all treatments are the same"; the Fobs value 0.64, which is less than the Fcrit. value, 3.47.

Table 3. 8:- The total coliform concentration count at Ashal at the end of one hour with mirror, aluminum foil and without activator.

| Without Activator	With Mirror	With Aluminum Foil	Control
80000	78000	60000	500000
75000	72000	75000	534000
83400	63000	73400	767000
83700	68700	53700	478000
65700	60700	68700	654000
75400	73400	70000	590000
78700	83700	68700	623000
69700	79700	59700	580000

Table 3.9:- The analysis of variance of different treatments at *Ashal kebele* at the end of six hours

source	df	SS	mean square	Fobs	Fcrit
Treatments	2	10.19444444	5.097222222	0.64001	3.47
within treatments	21	167.25	7.964285714		
total	23				

The average coliform concentrations for treatments within six hours are found in Table 3.10. The difference between the average coliform concentrations for the bottles cleaned by SODIS without no activator and the other treatment, with mirror and with aluminum foil averages is smaller than the LSD (3.55). Hence, the treatment either of methods (with mirror and with aluminum foil) as well as treatment without any activator for six hours makes not statistical different. Figure 3.2 is presented the disinfection efficiency of natural solar radiation disinfection increases with increasing contact time.

Table 3.10:- Average TC concentration at the end of six hours at *Ashal kebele*

Treatment	Average coliform
Without activator	20.375
With mirror	17.6
With aluminum foil	19.25
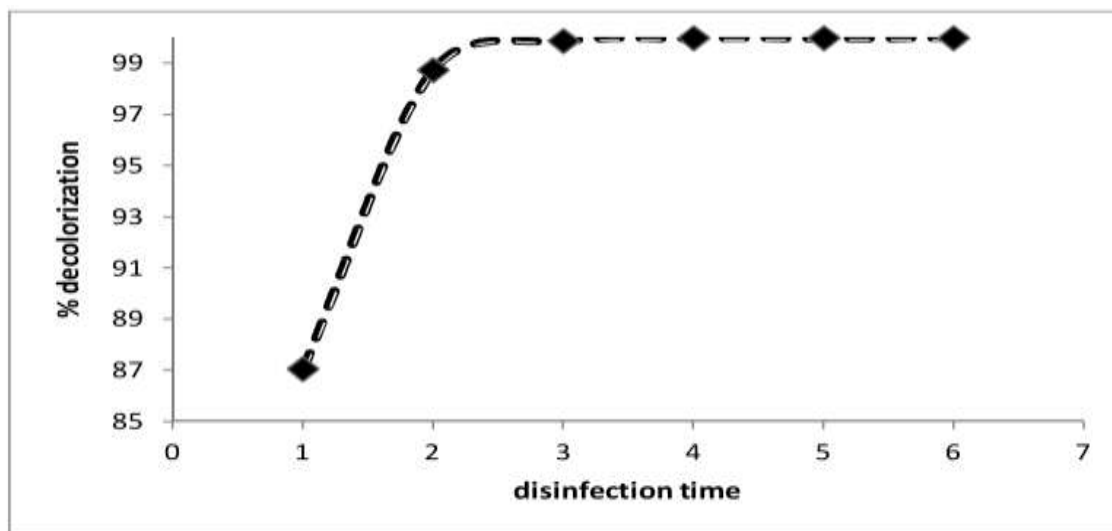
Figure 3.2:- The disinfection efficiency of natural SODIS at *Ashal kebele*

Conclusion:-
In conclusion, the disinfection of river and pond water for potable purpose using SODIS vary with different activators. The use of mirrors and aluminum foils increases significantly the efficiency of solar treatment of water and improves the quality of water in a shorter time compared with treatments without any activators. Exposure time

of the sample with solar radiation in the first three hours brought a significant effect however the time goes at the end of five and six hours treatment with mirror, aluminum foil and without activator have not significant difference. At the end of six hours almost 99.9 % of the water disinfected effectively.

Acknowledgments:-

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