AIJHA
Aloha International Journal of Health Advancement (AIJHA)
ISSN 2621-8224
Volume 4 Number 2, February 2021
RESEARCH
http://journal.aloha.academy/index.php/aijha
DOI: http://dx.doi.org/10.33846/aijha40204

Development of Solar Chlorinator for Clean Water Disinfection for Communities

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Submitted: January 1, 2021 -Revised: February 1, 2021 -Accepted: February 4, 2021 -Published: February 28, 2021

ABSTRACT

This study aims to improve the performance of digital solar chlorinators to disinfect clean water for the community. In this experimental study, a digital solar chlorinator was made for disinfection of clean water by testing performance with variations in distances of 0 m, 500 m and 1000 m, resulting in residual chlorine < 0.7 ppm and *E coli* bacteria. Chlorinator specifications are: solar cell panels; DC Converter stabilizer and Digital current voltmeter; Control solar cell system and battery changer; battery; adjustable velocity; peristaltic pump (pump chlor) using geer bok; control switch internet system or internet controller semiconductor (ICS) that uses a modem; submersible pumps; digital peristaltic pump water flow regulator which is assembled in the system. Performance of chlorinator peristaltic pump discharge: 45 liters/day (85 gram/day of chlorine) at source water flow rate of 1.1 liters/second, the results obtained: residual chlorine at distances of 0 m, 500 m and 1000 m respectively: 0.56 ppm, 0.43 ppm and 0.28 ppm (meets the regulation of the minister of health). It is necessary to further investigate how long the level of resistance, service life, operation and maintenance of the chlorinator is needed. The performance of the solar cell chlorinator with digital devices makes it easier to operate and maintain and can be applied to various discharges.
Keywords: digital solar chlorinator; chlorine; water sources; *E coli*

INTRODUCTION

The provision of clean water in rural and urban areas must be ascertained whether it meets health requirements, so that health problems do not occur, especially the spread of digestive tract diseases such as diarrhea, typhus, cholera and so on. To overcome these conditions, a chlorinator with the active ingredient of chlorine for running water can be used with appropriate technology that is inexpensive, local materials, easy to manufacture and easy to operate and maintain.

Chlorination is an attempt to disinfect water from living microorganisms in water using chlorine. With a short contact time (10 minutes), chlorine was able to reduce the number of *E. coli* bacteria drastically [(1)]. In determining the chlorination crack point, if the dose of active chlorine is increased, the residual concentration of active chlorine will increase [(2)]. The disadvantage of using excessive chlorine will cause body irritation, the water will smell and taste, and in powder form it will be easily carried by the wind. Chlorinators that use chlorine powder are often clogged, corrosive to submersible pumps. The remaining chlorine in the source water flows far away, causing the residual chlorine to decrease accompanied by a decrease in the effectiveness of the disinfectant [(3)].

The use of chlorine at doses of 350 ppm, 450 ppm and 550 ppm showed that the remaining chlorine still met the maximum limit of health requirements [(4)] with the addition of 25 ppm alum + 10 ppm chlorine, because the highest DO value and the lowest COD and BOD were obtained [(5)]. The purpose of this research is to design a digital solar chlorinator for disinfection of clean water for the community.

METHODS

This experimental study used a one group pre and post-test design. The research team treated water samples that were disinfected using a Solar chlorinator to produce water with residual chlorine of 0.7 ppm according to the Minister of Health of the Republic of Indonesia No. 492/2010 on requirements for drinking water quality [(3)]. The performance test of the tool includes: chlorine absorption, residual chlorine, odor, taste, pH and pathogenic bacteria (*E coli*) at a distance of 0 m; 500 meters; 1000 meters. The object of this research is water from a water source in Panekan village, Panekan sub-district, Magetan regency, Indonesia.

The chlorinator testing process was:

1) Prepare the solar cell screen equipment so that it can receive sunlight to produce energy that is channeled through the cable to the control box mechanic. DC Converter stabilizer equipped with a Digital current voltmeter which will show the voltage from the sun's energy (maximum 14 volts)
2) Place the mechanical control box that is connected under the solar cell screen
3) Observing the DC Converter stabilizer which is equipped with a Digital current voltmeter which will show the voltage from the sun's energy (max. 14 volts).
4) Observing the control of the solar cell system which is equipped with an adjustable velocity that functions as a distributor of energy for charging the battery/accu. The digital screen will show the battery voltage capacity. If

charging is successful, the voltage on the battery will increase to a maximum of 14.2 volts, then the adjusttable velocity will turn off. This will give battery maintenance more durable. However, if the battery voltage due to the use process decreases to 10.9, the Adjusttable velocity will automatically charge until the battery reaches 14.2 volts.

5) Ensure that the solar cell system control is connected to the internet control switch system or semiconductor internet controller (ICS) as the power provider for the device.

6) Connect the submersible pump jack cable to the control box mechanic, then connect the jack cable from the Automatic water level (radar)

7) Enabling automatic water level (radar) and submersible pumps to fill water into the chlorine tank. The device will function under the following conditions:
   a) Chlorine solution reduced by 40 -50 liters will turn on the submersible pump to fill water.
   b) Automatic water level will turn off the submersible pump if it has filled 40 -50 lt. Thus the chlorine solution tank will be safe from lack of water and excess water.
   c) Automatic water level of this tool can actually be adjusted according to the water level level of the user.

9). Enable the Internet system control switch or semiconductor Internet controller (ICS) tool to turn on or turn off the peristaltic pump (chlorine pump). This tool is equipped with a relay lamp and a signal lamp that will indicate the internet can work or not.

10). Filling drums of chlorine solution (2 drums with a capacity of 190 liters)

11) Enabling the peristaltic pump (chlorine pump) to add chlorine solution to raw water by adjusting the flow control switch to increase and decrease the chlorine solution flow rate as needed (capacity up to 200 ml/minute). The discharge control display must be observed to determine whether the chlorine pump is in the on or off position, which is indicated by the red LED on and off. Connect the peristaltic pump inlet hose to the chlorine solution drum.

12). Enable the internet system control switch or the semiconductor Internet controller (ICS), to turn the chlorine pump on or off until it functions properly.

13). Evaluating tool performance

RESULTS

The average discharge of water entering the reservoir is 1 liter/second and the calculation of the need for chlorine is:

$$\frac{(Q)x(DSC+SC)}{\%chlorine}$$

$$= \frac{(1.1\ l/s)x(0.2\ ppm + 0,57\ ppm)}{90\%}$$

= 81 grams/day

If dissolved in 45 liters of water, then the discharge of the solution in a day can be calculated as follows:
45 x 1000 ml/day or 31.25 ml/minute

Table 1. Results of measurement of residual chlorine in reservoirs and household piping networks

Day	Time measurement (hours)	Location of measurement (distance to drop the chlorine solution)						Remarks
		Distance 0 m		Distance 500 m		Distance 1000 m		
		Remaining Chlorine (ppm), replication:		Remaining Chlorine (ppm), replication:		Remaining Chlorine (ppm), replication:		
		1	2	1	2	1	2	
1	08.30-09.30	0.7	0.6	0.5	0.4	0.4	0.4	Regulation of the Minister of Health of the Republic of Indonesia No. 492/Menkes/Per/IV/2010 concerning: Requirements for drinking water quality (remaining chlorine: <0,7 ppm)
	12.30-13.30	0.6	0.6	0.5	0.5	0.3	0.4	
	14.30-15.30	0.7	0.6	0.4	0.4	0.4	0.4	
2	08.30-09.30	0.7	0.7	0.4	0.5	0.4	0.3	
	14.30-15.30	0.6	0.5	0.5	0.4	0.4	0.3	
3	08.30-09.30	0.6	0.5	0.5	0.4	0.4	0.4	
4	08.30-09.00	0.5	0.5	0.4	0.5	0.2	0.2	
5	08.30-09.00	0.6	0.6	0.5	0.5	0.3	0.3	
6	08.30-09.00	0.6	0.6	0.5	0.4	0.1	0.3	
7	08.30-09.00	0.5	0.6	0.4	0.4	0.1	0.3	
8	08.30-09.00	0.5	0.5	0.4	0.4	0.2	0.2	
9	08.30-09.00	0.4	0.5	0.3	0.3	0.2	0.3	
10	08.30-09.00	0.4	0.5	0.4	0.3	0.2	0.3	
Average		0.56	0,56	0,44	0,42	0,26	0.31	
The average of replication 1 and replication 2		0,56		0,43		0.28		

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Table 2. Measurement results of temperature, pH, odor and E coli bacteria in reservoirs and household piping networks using a chlorinator

No	Parameter											
	Average temperature over distance:			Average pH at the distance:			Smell at distance:			E coli bacteria (per 100 ml)		
	0 m	500 m	1000 m	0 m	500 m	1000 m	0 m	500 m	1000 m	0 m	500 m	1000 m
1	25.4	25.4	24.8	7,1	7.0	7,2	Tbs	Tbs	Tb	0	0	0
2	25,0	25,5	25,5	7.1	7.2	7,0	Tbs	Tbs	Tb	0	0	0
3	25.4	25.5	25,5	7.3	7.0	7.2	Tb	Tbs	Tb	0	0	0
4	25,5	25.5	25.6	7.0	7.0	7.2	Tbs	Tb	Tb	0	0	0
5	25.5	25.5	25.5	7.2	7.2	7,0	Tbs	Tbs	Tb	0	0	0
6	25.5	26,0	25.5	7.0	7.0	7,1	Tb	Tb	Tb	0	0	0
7	25,5	25.5	24.5	7,0	6.9	7,1	Tbs	Tbs	Tb	0	0	0
8	24,5	25,2	25.5	7,0	7,0	7,1	Tbs	Tbs	Tb	0	0	0
9	25.3	25,5	25.8	7,0	7,0	7,1	Tbs	Tb	Tb	0	0	3
10	24,5	25,0	24.8	7.0	7,0	7,1	Tbs	Tbs	Tb	0	0	0
	25.21	25.49	25.30	7.07	7.03	7.13				0	0	0,03

Tb = odorless Chlor;
TBs = Slightly smell of chlorine
The results of MPN Coliform examination in the reservoir before treatment were 42 cells/ 100 ml, 39 cells/100 cells/ 100 ml, 29 cells/ 100 ml.

DISCUSSION

Preparation of Chlorine Solution

In determining the chlorine requirement, 5 replication tests were carried out with a water discharge of 1 liter/second required an average of 0.77 ppm chlorine (average remaining 0.57 ppm chlorine and 0.20 ppm chlorine absorption). This is in accordance with the Regulation of the Minister of Health of the Republic of Indonesia No. 492/Menkes/Per/IV/2010 concerning Drinking Water Quality Requirements, namely residual chlorine 7 ppm [3]. The above information will be used to determine the need for chlorine solution through a set of solar cell chlorinator tools by taking into account the balance of the chlorine solution discharge through the device and the source water discharge. The use of chlorine pills has the advantage that the chlorine solution does not precipitate. This is different from the use of chlorine in powder form.

By using 2 pills of chlorine which are put in a drum with a volume of 190 liters, then allowed to stand for 1 day, a chlorine solution of 1 to 1.5 ppm is produced. The next step is setting the discharge of the chlorine peristaltic pump in the reservoir tank.

Results of Measurement of Residual Chlorine in the Reservoir and Parcel Pipelines

The remaining good chlorine from dripping on the reservoir (0 m), 500 m and 1000 m piping network varies between 0.20 to 0.7 ppm. (according to the Regulation of the Minister of Health of the Republic of Indonesia No. 492/Menkes/Per/IV/2010 concerning Requirements for Drinking Water Quality, i.e. residual chlorine 7 ppm) [3].

Chlorine can kill bacteria by inhibiting protein synthesis, nucleic acid synthesis, cell wall synthesis, destroying metabolism and this results in dead or destroyed bacteria. This compound contains about 70% active chlorine and is the most widely used chemical for disinfection [2]. The presence of residual chlorine in the water indicates the loss of pathogenic bacteria such as coliforms, E coli. With a contact time of 10 minutes, the nature of chlorine as a disinfectant is able to reduce E coli bacteria by a drastic amount and even up to 40 minutes of contact. However, the disinfectant ability will decrease as the remaining chlorine decreases [1, 6].

In this study, the chlorine solution through a peristaltic pump with a measurable discharge is dripped into the reservoir, then the water will flow through the network pipe to the consumer. In the process of the journey, the process of mixing the chlorine solution and raw water takes place and the disinfection process occurs until there is no bacteria which is indicated by residual chlorine in the raw water. Residual chlorine 0.2 – 0.5 ppm can kill bacteria in HIPPAM Tirto Sejati, Gresik Regency [4]. Chlorine can be an oxidizing agent that will remove iron and manganese compounds dissolved in water. In the chlorine solution there is HClO which will release oxygen atoms and these atoms are actually active in killing bacteria and microorganisms in water. The more HClO that is formed, the more oxygen atoms are released, which means the disinfection power is greater. This condition will also be able to reduce TSS levels in the water. [5]

The longer the water in the distribution will be at risk of lowering the quality of the water in the distribution system. This is caused by the interaction between the pipe wall and the water and the reaction of the water in the pipe. The reaction will continue and the water undergoes chemical, physical and biological reactions. So the longer the water is in the network, the more reactions that occur in the water in the system so that the water quality changes. [7]

This study shows that the distance of water distribution from the reservoir to the customer affects the decrease in residual chlorine in the customer. In the reservoir, the remaining chlorine (0.7 ppm) after being distributed at 1000 m decreased to the lowest 0.2 ppm. This is due to the distance it takes for water to reach the customer and the reactions that occur in the system while the water is in the pipes. There is a tendency that the farther the distance between the reservoir and the consumer, the smaller or less residual chlorine. [8]

Customers close to the reservoir have a fairly high residual chlorine, which is above 0.5 mg/l so that it has a negative impact on customers because the high residual chlorine can react with organic matter in water which causes corrosion of pipes and water can become carcinogenic.

Whereas in the simulation, if you use the injection of a chlorine concentration at the beginning of the water distribution of 0.8 mg/l, it will produce residual chlorine that meets the allowable residual chlorine limit of 0.2-0.5 mg/l but that only happens to close customers. with reservoirs. For customers whose water distribution distance is quite far from the reservoir, the remaining chlorine will be exhausted in the network system so that the remaining chlorine produced by customers who are far from the reservoir is less than 0.2 mg/l. This can also have a negative impact because if the remaining chlorine is less than 0.2 mg/l to the customer, the pathogenic bacteria in the water will still remain. The purpose of disinfection is to eliminate pathogenic bacteria in clean water, but if the residual chlorine is less than 0.2 mg/l, the pathogenic bacteria will still have an impact on the health of customers if they consume the water. It can be concluded that the injection of chlorine concentration that can be used is in the range of 0.8 – 2.0 mg/l.

The concentration of residual chlorine in the distribution network affects the distance from the reservoir to the consumer, the farther the distance traveled by water, the concentration of residual chlorine decreases. The greater the distance, the lower the residual chlorine value [6]. The water in the pipe farthest from the reservoir shows a residual chlorine value of 0.1 mg/l, the pressure in this pipe is low causing a large decrease in chlorine content. Detention time (dwelling time) of water in the piping network will also affect the water disinfection process. The slower the flow velocity, the longer the residence time, and vice versa, the faster the flow velocity, the shorter the residence time. Bulk reaction can also increase with increasing temperature.

A residual chlorine value of at least 0.2 mg/l is required to ensure that certain pathogenic microorganisms have died and to prevent certain pathogenic microorganisms from living as long as the water is in the pipeline, if the residual chlorine value is <0.2 mg/l, water quality is not guaranteed. drinking from contamination by pathogenic microorganisms. However, the residual chlorine value is high, which is >0.5 mg/l. This value can be toxic and carcinogenic for customers who consume it, can accelerate corrosion of pipes, and cause taste and odor to water. The smell of chlorine in water can be used as an indicator of the presence of excess chlorine that is not in accordance with the standards set for drinking water

Results of Examination of pH, Temperature, Odor and *E coli*

Temperature

The average temperature at a distance of 0 m, 500 m and 1000 m ranges from 25.21 to 25,490 C. Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 492/2010, the temperature is still eligible. The small difference in temperature and cold (25 oC) indicates a small difference in residual chlorine in raw water. The higher the temperature in drinking water, the lower the residual chlorine content. The increase in temperature is only 0.5ºC with a decrease in residual chlorine of 0.24 mg/l. [9] The results of the inspection of piped water temperature increased in the distribution network by 0.6ºC in the remaining chlorine 0.45 mg/l to 0.0975 mg/l. [10]

pH

The results of the average pH measurement at a distance of 0 m, 500 m and 1000 m ranged from (7.03 oC to 7.13 oC) which met the requirements as drinking water (Permenkes RI No. 492/2010) [3]. The decrease in residual chlorine in the piping network (0 – 1000 m) was not affected by the pH conditions in the water, but the decrease in residual chlorine in the water was influenced by the disinfection process during the distribution of piped water and the retention time of water in the network. According to [2] that the effectiveness of chlorine is also influenced by the pH of the water. Chlorination will not be effective if the pH of the water is more than 7.2 or less than 6.8.

In the research results, the residual chlorine was 0.479 mg/l with a pH of 7.27 and the remaining chlorine was 0.142 mg/l with a pH value of 8.12. [9] The residual chlorine will decrease as the pH value increases with the results of the examination of residual chlorine of 0.45 mg/l at a pH of 7.674 to a residual chlorine of 0.0975 mg/l at a pH of 8.575. Changes in pH in water are related to the work of chlorine. [10]

The higher the pH of the distribution water, the lower the residual chlorine value in the water distribution network of the Cileng IPA PDAM Lawu Tirta Magetan. [11]

Smell

The results of odor measurements showed that the residual chlorine content (0.4 -0.7 ppm) at the point 0 - 500 m in the distribution network showed a slight smell of chlorine. While the concentration below 0.4 ppm at a distance of 1000 m does not cause odor. There are indications that the farther the distance from the point of affixing the raw water chlorine solution, the less the smell, and the lower the chlorine concentration. According to the high residual value of chlorine, which is > 0.5 mg/l, it can be toxic and carcinogenic to customers who consume it, can accelerate corrosion of pipes, and cause taste and odor to the water. The smell of chlorine in water can be used as an indicator of the presence of excess chlorine that is not in accordance with the standards set for drinking water [(6)].

E coli bacteria

The content of E coli appears at a distance of 1000 m at the position of the remaining 0.10 ppm chlorine per 100 ml sample. While at a distance of 0 m and 500 m there is no E coli bacteria because the residual chlorine ranges from (0.56 to 0.43 ppm). This shows that the residual chlorine in the water is more than 0.43 ppm free of coli bacteria but the residual chlorine should not be more than 0.7 ppm (Permenkes RI No. 492/2010) [(3)]. This condition shows that the residual chlorine in the source water flows further, the residual chlorine content will decrease along with the effectiveness of the disinfectant will also decrease.

The presence of residual chlorine in the water indicates the loss of pathogenic bacteria such as coliforms, E coli. In disinfection, the speed and effectiveness of the disinfectant depends on several factors [(12)] namely the type of microorganism, the number of microorganisms, the age of the microorganism, the distribution pattern, the type and concentration of the disinfectant, the contact time, environmental factors (temperature, pH, water quality).

Testing for E coli bacteria was carried out on the distribution network (areas with the lowest residual chlorine), no E coli bacteria were found in the water (9). The chlorine injection device in a 1,000 liter dug well using 20.97 grams of chlorine is capable of disinfecting for 16 days, the water is odorless, tasteless and free of coliform bacteria [(13)].

CONCLUSION

Based on the results of the study concluded as follows:

1. The need for chlorine is 81 grams / day dissolved in 45 liters of water for a drip rate of 31.25 ml / minute (45 liters / day) can be used at an average source water flow of 1.1 liters / second
2. The performance of the chlorinator in an effort to provide clean water that is suitable for public consumption are: peristaltic pump discharge: 45 liters/day at source water flow of 1.1 liters/second, the results are: residual chlorine at a distance of 0 m, 500 m and 1000 m respectively. -average: 0.56 ppm, 0.43 ppm and 0.28 ppm

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