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Solar Cell as Energy Chlorinator for Disinfection of Flowing Water

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ABSTRACT

The provision of clean water for the community must pay attention to physical, chemical and bacteriological requirements and this is intended to avoid negative impacts that are detrimental to its use. The purpose of this research is to produce a solar cell device as a chlorinator energy used to disinfect running water for the needs of the community. Experimental research to determine the performance of the tool to produce residual chlorine and *E. coli* in flowing water with variations in distance of 0 m, 0.5 km and 1 km according to the standards of the Ministry of Health 32/2017. The results of the research using a chlorinator consisting of a solar cell, battery, modem internet system, equipped with a signal lamp and relay lamp, a peristaltic pump as an injection of chlorine solution and a disinfectant used as a chlorine solution. The need for chlorine is 1.63 mg/l (141 g/day) dissolved in 40 l, then peristaltic pump discharge: 28 ml/minute for disinfection at reservoir water discharge 1.13 l/s, the result is: residual chlorine on average at a distance of 0 km, 0.5 km and 1 km respectively 0.64 ppm, 0.49 ppm and 0.3 ppm and contains *E coli* (0 per 100 ml), except for replication 11 which is 2 per 100 ml and still meets the requirements clean. The chlorinator can be used but it still needs to be tested regarding the durability of the components, the manufacture of digital devices, namely pump discharge, control switch internet system, automatic signal in case of trouble.

Key words : *Chlorinator, Chlorine, Water and E coli.*

Introduction

The pattern of providing clean water for the community must pay attention to physical, chemical and bacteriological requirements (Permenkes, 2017) and this is intended to avoid negative impacts that are detrimental to its use. Springs through bound captering are often susceptible to bacteriological contamination that causes stomach ailments such as: vomiting, typhus, cholera, dysentery. To eliminate bacteria, especially those that are pathogenic, ultraviolet technology, chlorine gas disinfection, affixing chlorine and many other technologies can be used with consideration of several aspects of the effectiveness and efficiency of these technologies (Mulia Rickim, 2016).

The active ingredient of chlorine in chlorine is often used because the residual chlorine in the water is able to kill pathogenic bacteria, the price is affordable, easy to obtain and the technology is simple to use. Through a chlorinator that uses chlorine as a disinfectant, it can be relied upon to kill e coli bacteria in running water (Sujangi *et al.*, 2017a). Chlorine comes from gas Chlor (Cl2), NaOCl, Ca(OCl)2, (Caporite) or HOCl solution (Hypochloric acid). When these compounds react or are dissolved in water, a hydrolysis reaction will occur rapidly (Mulia Rickim, 2016).

The use of chlorine which has disinfection power up to several hours after affixing as long as the remaining chlorine in the water is still there, the bacterial disinfection process will continue and will stop if the remaining chlorine is used up. The impact of excessive use of chlorine will be able to cause body irritation, cause unpleasant odors and tastes in water, in powder form, easily carried by the wind (Ocktaviannus Amen *et al*., 2012).

The results of the research in the IPA installation of HIPPAM Tirta Sejati, Karangrejo Village, Manyar District, Gresik Regency, the use of chlorine which produces residual chlorine: 0.2 to 0.5 ppm according to the standard of Minister of Health Regulation No. 416/Menkes/Per/IX/1990) but the farther the installation distance, the greater the number of *E coli* (Pujirahayu and Sugito, 2014).

With the addition of 25 ppm alum +10 ppm chlorine in the Lambidara river water treatment unit in Palembang, it can increase the highest DO value and the lowest COD and BOD (Tamzil Aziz *et al.,* 2013).

A chlorinator that uses solar cell energy in a submersible pump to provide a chlorine solution of 185 g/day in 9.25 liters of water for a discharge of 1 l/s at a distribution distance of 1000 m is capable of producing residual chlorine from 0.2 to 0.5 ppm. However, submersible pumps are manual tools, easily corrosive, the use of chlorine powder is an obstacle for the chlorine distribution line to be easily clogged (Sujangi *et al.,* 2017a). This follow-up experimental study aims to improve the performance of a chlorinator with a peristaltic pump for disinfection of clean water.

Materials and Methods

Experimental research using a chlorinator consisting of components of a solar cell, battery, internet modem system, equipped with a signal lamp and relay lamp, peristaltic pump as injection of chlorine solution and disinfectant used as a chlorine tablet. Disinfection process in running water to produce water that has residual chlorine 0.7 ppm ((Permenkes, 2017). Performance testing of this tool is about: chlorine absorption, residual chlorine, odor, temperature, pH and pathogenic bacteria (coli bacteria) at a distance of 0 km; 0.5 km; 1 km. Population and research sample: water in the reservoir before being distributed in the village of Rejomulyo, Panekan District, Magetan Regency.

The components of the chlorinator include 1) Solar cell size 35x50 cm: as an energy source that can drain a voltage of 21.6 volts to the battery charger, 2) battery charger: a device that functions as a charger for 12/7.5 Ah batteries. 3) battery: storage of power to drive the peristaltic pump, 4) peristaltic pump: pump used for dripping the discharge of chlorine solution on water samples. 5) The internet system modem functions as a tool that can be used to turn on and or turn off the peristaltic pump remotely if needed at any time (eg at night), 6) Chlorine tablets (disinfectant material) The tools and materials used are assembled in a mechanical box with Pay attention to the operation and maintenance of the equipment to function optimally.

The implementation phase of this research experiment; 1) Prepare tools and materials, 2) Measure the discharge of water sources. Cipolity weir Q = 1,859 LH 3/2 (Ket: Q = discharge (lt/s), L = channel sheet (cm), H = overflow water height (cm), 3) Measure residual chlorine content, DSC, pH, temperature, coli bacteria, odor, in water before the disinfection treatment process with a chlorinator. 4) Measuring the need for chlorine for disinfection so that the remaining chlorine in the source water is 7 ppm (1), 5) Make a solution of water and chlorine for every 2 days. 6) Install the chlorinator in the water reservoir and ensure that the device functions properly to produce residual chlorine 7 ppm with 15 replications each. 7) Check the residual chlorine content, DSC, pH, temperature, coli bacteria, odor, in the water source after the disinfection process with a chlorinator with various locations (distance): (at water source: 0 m; 0.5 km, 1 km) 9) Enter the results of the inspection in the table to analyze the effectiveness and capacity of the chlorinator. 10) Repeat the above procedure with the chlorinator until performance meets the requirements of the Minister of Health: 32/2017.

Results

Flow Discharge and Chlorine Requirement

The average water discharge entering the reservoir is 1.13 l/s and the calculation of daily chlorine requirement with 5 replications is obtained:
Chlorine requirement for samples of water sources

with discharge 1,13 l/s $= \frac{\{Q\} x (DSC + SC)}{KK}$

$$= \frac{\{1,13 lt/s) x (0,60 ppm + 0,7 ppm)}{90\%} = 1,63 \text{ mg/l}$$

The need for chlorine is 1.63 mg/l (141 g/day) dissolved in 40 liters, the peristaltic pump discharge: 28 ml/minute.

Results of Measurement of Remaining Chlorine in Reservoirs and Piping Networks

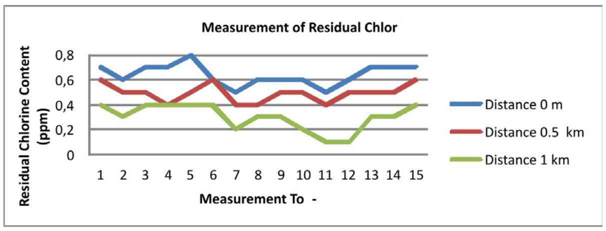

Fig. 1. Results of measurement of residual chlorine in the reservoir and household piping network using a Chlorinator

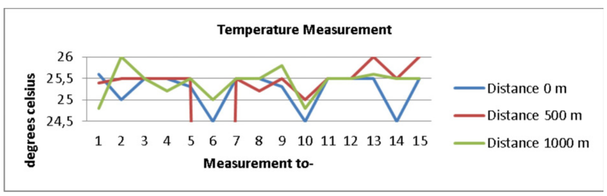

Fig. 2. Results of temperature measurements in the reservoir and household piping network using a chlorinator

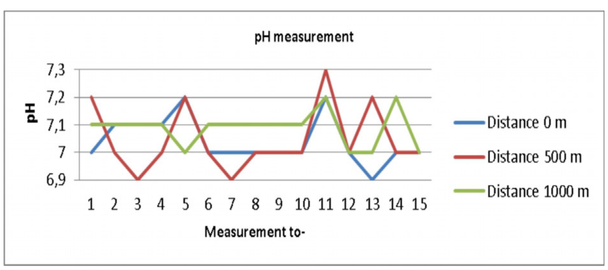

Fig. 3. Results of pH measurements in reservoirs and household piping networks using a chlorinator

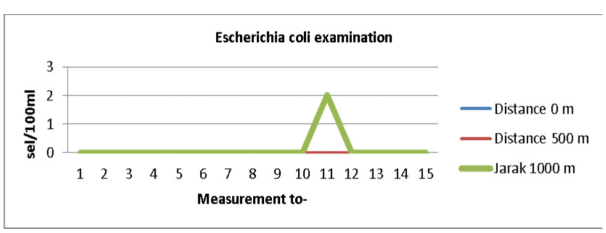

Fig. 4. Measurement results of *E coli* bacteria in reservoirs and household piping networks using Chlorinator Chlor

Discussion

Performance of the chlorinator

The description of the performance of the chlorinator is 1) Placing the solar cell screen with a slope of 30 degrees so that it can receive sunlight and produce energy on the Digital current voltmeter (maximum 14 volts) in the mechanical control box under the solar screen to be safe and protected from heat and rain so as to maintain durability. and durability of the tool. 2) Adjustable velocity which functions as an energy distributor for charging the battery runs normally if the battery voltage indicator rises to a maximum of 13.8 Volts, then the Adjusttable velocity will turn itself off. However, if the battery voltage decreases to 10.9 volts, it will automatically charge until the battery reaches 13.8 volts. In normal sunlight conditions, solar cell heating takes 3-4 hours, the battery will die and is sufficient for 24-hour operation, meaning that during operation there is no shortage of power from the battery. 3) The internet system modem is equipped with a LED light indicator. If the light is on, it means normal function and or vice versa. This tool is connected to a peristaltic pump (chlorine solution pump) to turn on and or off remotely. From the results of practical studies in the field, the sympathy card is the easiest to operate. 4) Peristaltic pump (chlorine pump) in applying chlorine solution to the water in the reservoir by adjusting the discharge control switch to increase and decrease the flow rate of the chlorine solution as needed based on the calculation results by looking at the digital numbers on the device. The chlorine pump in distributing the chlorine solution with a predetermined discharge continuously to the water in the reservoir flowing in the distribution pipe. The balance of the discharge of the chlorine solution and the discharge of the source water being disinfected must produce residual chlorine of 7 ppm and must not be 0 ppm ((Permenkes, 2017).

Results of Measurement of Remaining Chloride in Reservoir and Persil Pipeline Networks

In graph 1: shows that the residual chlorine is good from dripping in the reservoir (0 km), the pipeline network 0.5 km and 1 km varies between 0.1 to 0.7 ppm. This condition still fulfills the requirements (Chlor residual) 7 ppm (Permenkes, 2017) that is in the distribution pipeline network that can be consumed, while at the 0 km point in the reservoir: 0.8

ppm. The discharge of the chlorine solution which is controlled by the peristaltic pump in the reservoir and then the water flows through the network pipe facilitates the mixing of the solution in water during the disinfection process. The farther the distance from the drop (reservoir) to the distribution network, the smaller the residual chlorine in the water. As long as there is residual chlorine in the water, there is no *E.coli*. The distance required for water to reach the customer and the reactions that occur in the system while the water is in the pipe show a tendency that the farther the distance between the reservoir and the consumer, the smaller or less residual chlorine. For this reason, customers who are close to the reservoir have a risk that the water consumed contains a high level of residual chlorine, which is above 0.6 mg/l although it still meets the requirements, but it is necessary to be aware of the negative impact of chlorine on health High chlorine content in water can damage pipes so it is corrosive and water can be carcinogenic.

The presence of residual chlorine in the water from 0.2 to 0.8 ppm makes the disinfection run perfectly, which is marked by the absence of *E coli* bacteria in the water. For consumers whose water distribution distance is more than 1 km from the reservoir, the remaining chlorine will be depleted in the network system so that the remaining chlorine produced by customers who are far from the reservoir is less than 0.1 ppm. This means that consumers will be at risk and receive negative impacts because pathogenic bacteria in the water are still remaining. To achieve the goal of disinfection to eliminate pathogenic bacteria in clean water, a concentration of residual chlorine in the water is needed in the range of 0.2-0.8 ppm so that pathogenic bacteria are not left in the water and consumers will be safe and healthy.

Chlorine containing chlorine as a disinfectant is able to kill bacteria by inhibiting protein synthesis, nucleic acids, cell wall synthesis, destroying metabolism and these results in dead or destroyed batteries (Sumbali and Mehrotra, 2009). With a contact time of 10 minutes, chlorine was able to reduce *E. coli* bacteria drastically even up to 40 minutes of contact and its disinfectant ability decreased as the remaining chlorine decreased (Puti Sri Komala and Ajeng Yanarosanti, 2015). The presence of residual chlorine from 0.2 to 0.5 ppm in the water indicates that *E. coli* is dead in HIPPAM Tirto, Gresik Regency (Pujirahayu and Sugito, 2014). HClO in a solution of chlorine in water will release oxygen atoms that are active in killing bacteria and microorganisms in the water. The more oxygen atoms released from the HClO in the water will increase the disinfection power. Chlorine solution in water is an oxidizing agent which will remove iron and manganese compounds dissolved in water and will also be able to reduce TSS levels in water (Tamzil Aziz *et al.,* 2013).

During the passage of water in the pipe during the water distribution system 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 (Sofia *et al.,* 2015).

The results of the study using the injection of 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 occurs in customers who are close to the reservoir. The concentration of residual chlorine in the distribution network affects the distance from the reservoir to the consumer, the farther the distance traveled by the water, the concentration of residual chlorine decreases. The longer the distance, the lower the residual chlorine value (Anggarini, Wiwin, 2017).

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 water from contamination by pathogenic microorganisms (Reri Afrianita *et al.,* 2016). However, a high residual chlorine value of >0.5 mg/l can be at risk of being toxic and carcinogenic to customers who consume it, can accelerate corrosion of pipes, and cause taste and odor in water. The content of chlorine in the water with a characteristic smell of chlorine shows an indicator that the remaining chlorine in the water exceeds the specified threshold (Permenkes, 2017).

Results of examination of pH, temperature, odor and *E.coli*

Results of Examination of pH, Temperature, Odor and *E.coli.* From graph 2 the results of the average temperature measurement at a distance of 0 km, 0.5 km and 1 km range from 24.8 to 26.0 ^{o}C still meet the requirements of Permenkes: 32/2017. The water temperature in the reservoir, which is located in the rice fields, still feels cold because the village of Rejomulyo, Panekan District is located on the eastern slopes of Mount Lawu and north of the administrative center of Magetan Regency. The difference in temperature of 10 ºC, it turned out to show the difference in residual chlorine 0.2 ppm in the water in the piping network. The smaller the difference in temperature of the disinfected water, the smaller the difference in residual chlorine in the water. The higher the temperature value in drinking water, the residual chlorine content will decrease. The increase in temperature was only 0.5 ºC with a decrease in residual chlorine of 0.24 mg/l (Reri Afrianita *et al.,* 2016). Likewise, research [12] obtained the results of checking the piped water temperature which increased in the distribution network, but was not significant. The temperature increased by 0.6 ºC in the residual chlorine 0.45 mg/l to 0.0975 mg/l.

Based on the results of the average pH measurement (graph 3) at 0 km, 0.5 km and 1 km measurements an average of 7.06 (ranging from 6.9 to 7.2) and in this condition the pH (neutral) still meets the requirements as drinking water (Permenkes: 32/ 2017). The average measurement results at the point 0 km (pH: 7.05 residual chlorine 0.64 ppm); at 0.5 km (pH:7.05 residual chlorine 0.49 ppm); while at 1 km (pH: 7.09 residual chlorine 0.3 ppm). This shows that the further the water travels through the piping, the pH distribution increases and is followed by a decrease in residual chlorine in the water. The distribution process in the pipe shows an indication of increasing the pH even though it is not much (0.04). The remaining chlorine that falls during the distribution of water because the disinfection process against microorganisms continues as long as there is residual chlorine in the water. With the reduction of residual chlorine, the pH of the water actually increases. Based on the results of research (11 and 12) that chlorination will be effective if the pH of the water is in the range of 6.8 - 7.2. The results of the measurement of residual chlorine were 0.479 mg/l with a pH of 7.27 and residual chlorine was 0.142 mg/l with a pH value of 8.12. This shows that a high pH results in a decrease in residual chlorine and vice versa. The absorption of chlorine is influenced by the amount of pH in the water and other factors such as microorganisms, the type of disinfectant.

At the residual chlorine concentration of 0.5 - 0.8 ppm in the water in the reservoir and piping network, there is an indication of a slight characteristic smell of chlorine, namely at a distance of 0 km and 0.5 km. Meanwhile, at a distance of 1 km and or more there is no indication of a typical chlorine odor with a concentration of residual chlorine in the water from 0.1 to 0.4 ppm. This shows that the farther the distance from the affixing point (reservoir) to the piping network, the residual chlorine content in the water decreases, followed by a decrease in the distinctive smell of chlorine in the water. The reduction of residual chlorine in the water to less than 0.1 ppm the water will not have a distinctive chlorine odor and cause the quality of drinking water to be not guaranteed from contamination by pathogenic microorganisms. (11) However, if the residue is > 0.2 ppm certain pathogenic microorganisms have died and can prevent the life of certain pathogenic microorganisms while the water is in the pipe network. The residual value of high chlorine is > 0.5 mg/l. can cause toxic and carcinogenic to 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 wáter (Wiwin Anggraini, 2015).

Graph 4: The content of *E coli* bacteria (3 cells per 100 ml sample) appears 1 time out of 10 replications at a distance of 1 km from the beginning of affixing in the reservoir and at the same time the position of the remaining chlorine is 0.18 to 0.20 ppm. Although the dose of *E coli* bacteria is very low, it is necessary to watch out for other types of bacteria, especially the pathogenic ones. For affixing chlorine solution at a distance of 0 km and 0.5 km there is no *E coli* bacteria (0 cells per 100 ml sample) because the average residual chlorine ranges from 0.49 to 0.62 ppm. This shows that the presence of residual chlorine in the water is more than 0.49 ppm free from pathogenic bacteria such as coliform, *E coli*. From the data above, the presence of residual chlorine in the water in the reservoir that flows in the distribution of pipes to consumers who are farther away, it turns out that the residual chlorine content will decrease (from 0.7 to 0.1 ppm) and accompanied by a decrease in the effectiveness of the disinfectant. The balance of the flowing discharge that is spiked with a chlorine solution is very important to obtain the residual chlorine results that are in line with expectations (Permenkes, 2017).

The discharge of the water to be disinfected shows a fluctuating number and varies at any time when different drops are needed. It is necessary for an effective and efficient chlorinator to be easy to use and maintain in field applications. In addition to the distance traveled by water in distribution to consumers, the number and types of microorganisms in the water also affect the chlorine absorption capacity (DSC), thereby reducing the residual chlorine in the water. During the water disinfection process using certain disinfectants, it is necessary to pay attention to reliability and safety for consumers so that they are not affected by negative health impacts and side effects of using these materials. Factors that affect the speed and efficacy during disinfection are (Wiwin Anggraini, 2015) namely environmental factors (temperature, pH, water quality), type and number of microorganisms, age of microorganisms, distribution patterns, type and concentration of disinfectant, contact time. The use of chlorine solution at a dose of 0.46 mg/l with a contact time of 30 minutes in the reservoir (initial disinfection) and piping network the number of *Escherichia coli* bacteria based on the MPN table is 0 cells/100 ml, which means that no Escherichia coli bacteria were found in the water (11). The content of residual chlorine in water to less than 0.1 ppm of water causes the quality of drinking water to be insecure from contamination by pathogenic microorganisms. In the range of numbers > 0.2 ppm residual chlorine in the water in the pipeline network, certain pathogenic microorganisms have died and are able to prevent certain pathogenic microorganisms from living.

Conclusion

Based on the results of research and discussion, it can be concluded that this chlorinator device consists of components of a solar cell, battery, modem internet system, equipped with a signal lamp and relay lamp, a peristaltic pump as an injection of chlorine solution and a disinfectant used with chlorine. The performance of the chlorinator: 1.63 mg/l (141 g/day) of chlorine, dissolved in 40 liters, the peristaltic pump discharge: 28 ml/minute for disinfection at 1.13 l/s reservoir water discharge, the result is: average residual chlorine average at a distance of 0 km, 0.5 km and 1 km respectively 0.64 ppm, 0.49 ppm and 0.3 ppm and the content of *E coli* (0 per 100 ml), except for replication 11 which is 3 per 100 ml and still meet the clean requirements of the Minister of Health Regulation number 32 of 2017. Efforts to provide clean water suitable for public consumption according to Minister of Health Regulation 32/2017 are: chlorine pump discharge: 20 l/hr at 1.27 l/s source water flow, the result is: residual chlorine in distances of 0 m, 500 m and 1000 m are 0.58 ppm, 0.450 ppm and 0.25 ppm, respectively. It is necessary to further investigate how long the level of resistance, service life, operation and maintenance of the chlorinator is needed.

The recommendation of this research is that it needs to be investigated further to improve the performance of chlorinator solar cells that use digital devices to simplify operations and maintenance and can be applied to various discharges.

Conflict of Interest: None

Source of Support: Self

Ethical Clearance: Ethical license is an approval from the Health Polytechnic Research Ethics Commission of the Ministry of Health Surabaya, this research does not use human and animal experiment objects, it only carries out surveys.

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