POTENTIAL OF SOLAR CELLS AS ENERGY DISINFECTION MACHINES FOR WATER SOURCES IN RURAL AREAS

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Abstract

Water from broundcaptering that will be consumed by the public must meet bacteriological requirements, especially *E. coli* bacteria and for that, disinfection is needed to eliminate them. The purpose of this research is to develop the potential of solar cells as a source of chlorinator energy for disinfection of clean water so that it is suitable for public consumption according to *Permenkes RI No. 492, 2010*. This experimental research method was to make a chlorinator from a solar cell energy source for disinfection using chlorine in clean water with performance testing, with variations in distance of 0 km, 0.5 km, 1 km, 1.5 km and 2 km resulted in residual chlorine <0.7 ppm and mpn coli. Components of the chlorinator consist of Solar cell panels; DC Converter stabilizer and Digital current voltmeter; Control solar cell system and battery changer; Battery; adjustable velocity; double membrane pump (chlorine pump) Control switch internet system or an Internet Controller Semiconductor (ICS) that uses a modem; Submersible pumps. The performance of chlorinators in an effort to provide clean water that is suitable for public consumption are: double membrane pump discharge: 50 lt/hr of chlorine at 1-1.5 lt/s source water flow, the results are: residual chlorine at a distance of 0 km, 0.5 km, 1 km, 1.5 km and 2 km respectively: 0.68 ppm 0.53 ppm, 0.45 ppm; 0.41 ppm and 0.29 ppm and free of mpn coli.

Keywords: chlorinator; disinfection; clean water; solar cell

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1. Introduction

Water is a key natural resource and a basic human need. It is also a foundation for public health and community welfare [1]. Water availability is a major problem that must be maintained every year and continue in the coming years [2]. The assessment comprises analysis of physical, chemical and microbiological characteristics of groundwater samples [3]. The provision of clean water managed by the community, whether sourced from broundcaptering or pumping, must meet physical, chemical and bacteriological quality standards [4]. It is important to note that people stay healthy and avoid various diseases through water, especially pathogenic bacteria. Chlorine is used for water disinfection because it is cheap, affordable and easy to use by the general public and has the power of disinfection for several hours after application. Disinfection using a chlorine solution in reservoir water with residual chlorine (0.28-0.56 ppm) is able to destroy e coli bacteria. The remaining chlorine in the tissue is less than this concentration can result in reduced disinfectant ability so that the number of pathogenic microorganisms increases [5].

The condition of the remaining free chlorine in the distribution network exceeding 0.5 mg/l can have a carcinogenic and toxic impact. The remaining chlorine concentration in the tissue is affected by the injection of the chlorine solution concentration at the beginning of the distribution and the distance from the reservoir [6]. The residual chlorine content below the quality standard results in high bacterial numbers. This is in line with the research of M. Noor, Z. et al. that there is a relationship between residual chlorine levels and Coliform [7]. Meanwhile, according to Tiwari et al. that sodium hypochlorite (NaOCl) has high effectiveness higher than 70% ethanol [8]. This is different from the ethanol solution which contains at least 70% ethanol to be used as a disinfectant. In addition, the disinfection process can also use a solution containing 10% formaldehyde, ammonium disinfectant, detergent and acid. The use of chlorine powder has encountered obstacles in the distribution of chlorine, which is easily clogged, corrosive to submersible pumps. Theremaining chlorine in the source water flows further away, the remaining chlorine content will decrease and the effectiveness of the disinfectant will decrease as well [9].

This research is a continuation of research on chlorinator design for community clean water disinfection [2] with several improvements, especially improving the performance of chlorinator components that can function optimally equipped with digital. The purpose of the research is to develop the potential of solar cells as a digital chlorinator energy source for public clean water disinfection. Among different types of renewable energies, solar energy is the most important one because of its zero-pollution, resource-free and economical characteristics [10-11]

2. Methods

This experimental development research used a one group pretest-post-test design [12]. Researchers carried out the potential of solar cells as a digital chlorinator energy source for disinfection of clean water in the sample group to produce water that has residual chlorine <0.7 ppm [4] concerning: requirements for drinking water quality. Performance tests related to: absorption of chlorine, residual chlorine, odor, taste, pH and mpn coli at a distance of 0 km, 5 km, 1 km, 1.5 km and 2 km. Water from water sources in Panekan village, Magetan, Indonesia.

Testing mechanism:

1. Measuring the discharge of water sources.
2. Checking residual chlorine content, DSC, pH, temperature, MPN coli, smell and taste, in water sources **before** the disinfection process with a chlorinator.
3. Measuring the need for chlorine for disinfection so that residual chlorine in source water is < 7 ppm (Permenkes: 492/ 2010).
4. Make a solution of water and chlorine as needed.
5. Install a digital chlorinator redesign tool in the water source to produce residual chlorine < 7 ppm with 15 replications each.
6. Checking residual chlorine content, pH, temperature, MPN coli, odor and taste, in water sources **after** the disinfection process with a chlorinator with variations in location (distance): (at water source: 0 km; 5 km, 1 km, 1.5 km and 2 km).
7. Analyzing research results.

3. Results And Discussion

Component of Chlorinator

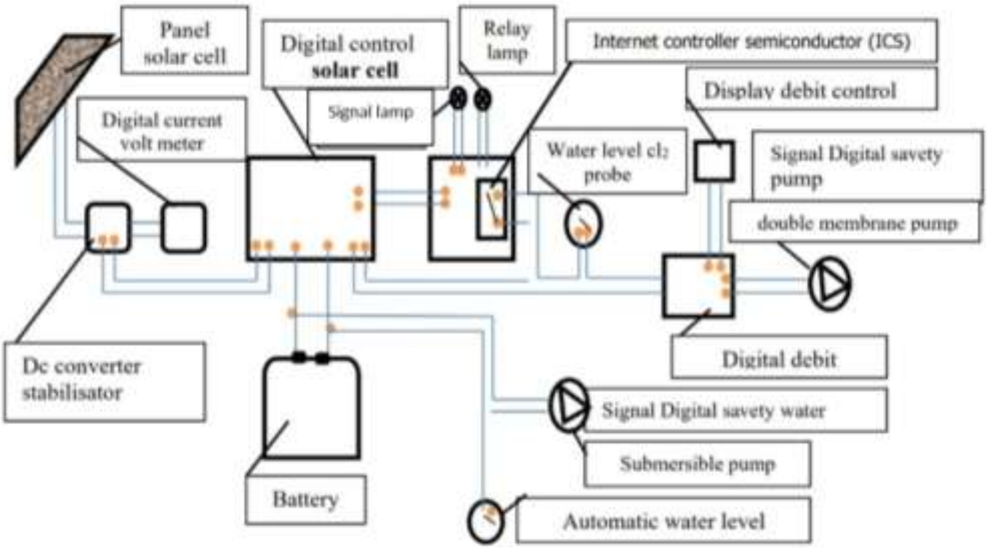

Figure 1: Component of chlorinator

The solar cell as an input can drain a voltage of 21.6 volts to the battery charger which functions as charging for the 12/7.5 Ah battery. The power from the dry battery is used to drive the DC double membrane pump which will produce a discharge of affixing the chlorine solution as needed from the chlorine tank to the water to be disinfected. This tool is also equipped with an Internet controller semiconductor (ICS) that functions as a tool that can be used to turn on and or turn off the DC double membrane pump remotely if needed at any time (ex. at night). The results of the measurement of the discharge in the reservoir of 1.5 lt/s required chlorine 92 g/day dissolved in 50 liters of water with a pump discharge of 35 ml/minute

Test Results of Solar Chlorinators in the Field: Residual Chlorine, pH, Temperature, MPN coli

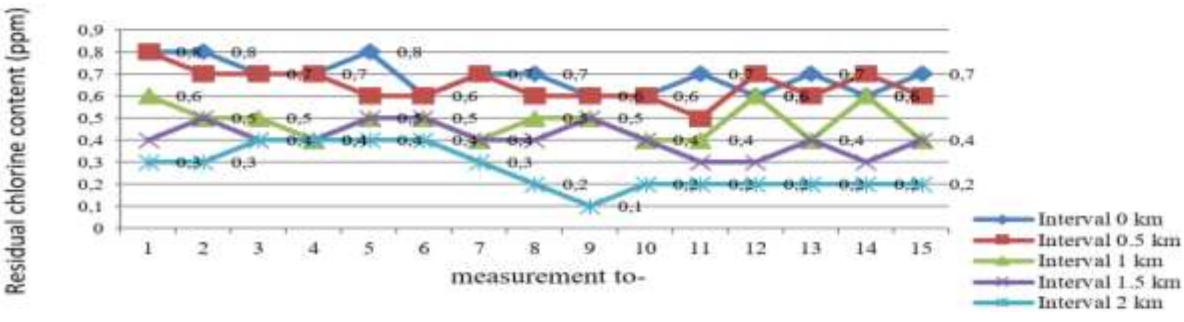

Figure 2: Residual chlorine in the reservoir and household piping network using a chlorinator

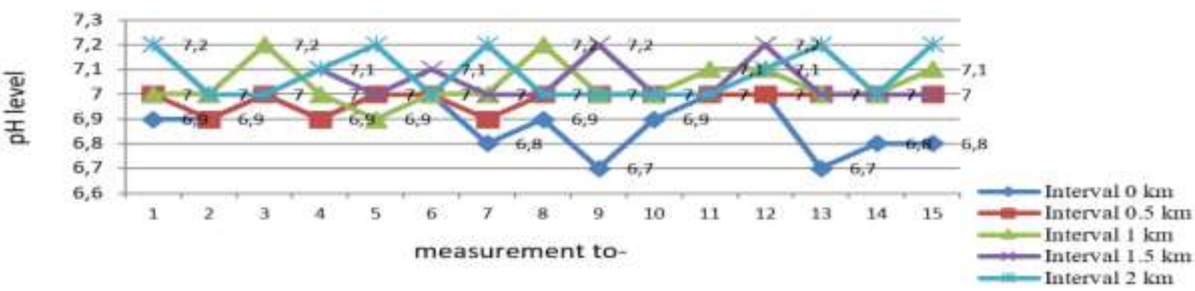

Figure 3: pH in reservoirs and household piping networks using a chlorinator

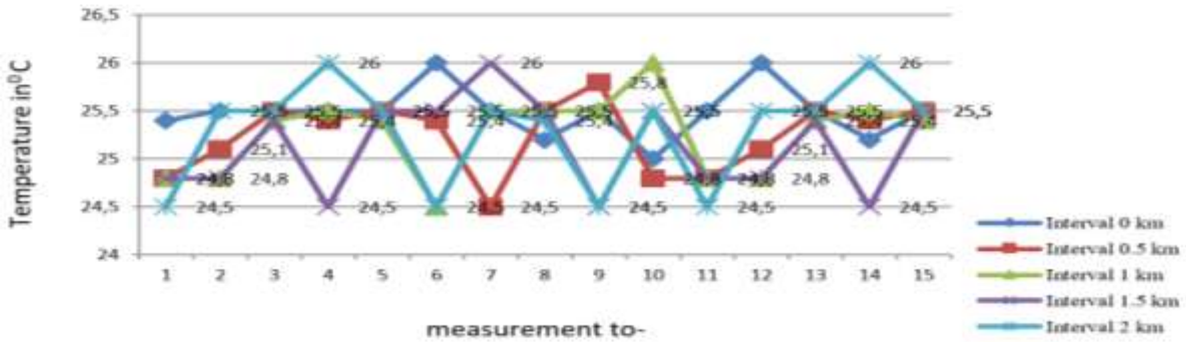

Figure 4: Temperature in the reservoir and household piping network using a chlorinator

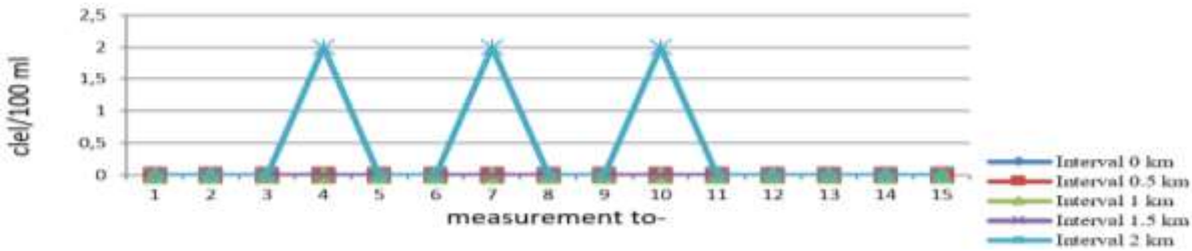

Figure 5: E coli bacteria in the reservoir and household piping network using a chlorinator

The Mechanism of Action of the Tool from the Chlorinator Component

Solar Cell

Test this tool must be able to provide power to charge the battery. The installation of the tool above the reservoir faces north with a slope of 40 degrees so that the solar cell screen can receive sunlight freely. The tool is connected by a cable to the mechanical control box. This can be controlled on the DC Converter stabilizer Digital current voltmeter monitored voltage from sunlight energy. (max 14.2 volts) and as long as the research process goes well.

DC Converter Stabilizer and Digital Current Voltmeter

The function of this tool as a battery charger circuit from a solar cell with a DC Converter stabilizer equipped with a Digital current voltmeter is functioning properly (see voltage indicator max 14.2 volts).

Battery

The battery can be charged from the Control solar cell system with a max capacity of 14.2 volts, the battery will be stable, not hot (burned) and will die at that voltage. If the use of excessive power in the mechanical control box up to a battery capacity of 10.2 volts, the tool will turn off and this is intended so that the components of the tool and the battery will remain safe.

Adjustable Velocity

This tool functions as a distributor of energy for charging the battery / battery so that it runs normally. The digital screen will show the battery voltage capacity which can go up and down according to the power consumption of the tool components. Charging the battery will increase to a maximum of 14.2 volts and a minimum of 10.2 volts, then the adjusttable velocity will automatically turn off. Under normal sunlight conditions, solar cell heating takes 2-4 hours, the battery will be full and sufficient for 72 hours of operation without sunlight

Double Membrane Pump

This tool is equipped with a digital flow control in a mechanical box that can be read on the screen (20 to 200 ml/minute capacity). This pump indicator works will make a clicking sound and if the discharge is getting bigger the sound will be faster and if the discharge is getting smaller then the sound will be slower. As another indicator, the outlet and inlet hoses will vibrate according to the sound in the mechanical box.

Other indicators such as the discharge does not flow and the pump is off, then steps are taken to control the submersible pump which does not fill the chlorine solution because the spare water in the drum runs out (below the lower level). If something like that happens, it shows that the regulating radar setting is really functioning and this can actually maintain the life of the pump. The solution steps are very simple, namely filling the water drum, then the Double Membrane pump will function normally again.

Control Switch Internet System or Internet Controller Semiconductor (ICS)

Observing the control switch internet system or internet controller semiconductor (ICS) as a power provider for the device to run normally according to its function. As an indicator installed LED lights. If the light is on, it means normal function and or vice versa. In the Control solar cell system, there is also an Adjusttable velocity which functions as a power regulator and a power provider for the double membrane chlorine pump when the on position and charging the battery as well as a power provider for ICS.

Submersible pump

The working mechanism of the Submersible pump supplies water to the chlorine solution drum. The mechanical box control that is connected to the pump requires a minimum cable length of 5 m because it really depends on the distance from the pump to the chlorine solution drum. The next job is to connect the jack cable from the Automatic water level (radar) in the chlorine solution. To function the Automatic water level (radar) and submersible pumps in filling water into the chlorine tank, it is necessary to set the height of 2 floats to a depth of 25-30 cm the height of the chlorine solution drum. As an indicator, the device will function under the following conditions:

1. Decreased chlorine solution by 30 - 40 liters will turn on the submersible pump to fill water.
2. Automatic water level will turn off the submersible pump if it has filled 30 -40 lt. Thus the chlorine solution tank will be safe from lack of water and excess water.
3. Automatic water level of this tool can actually be adjusted according to the level of the water level of the user. As an indicator of pump life, a red LED light is used. Therefore, in the next research, a set of electronic devices is needed that is able to detect the flow rate so as to facilitate the control mechanism of the device.

Digital Debit Controller

The specifications of this tool are used to digitally adjust the flow rate with a range of 20 to 200 ml/minute (depending on the needs of the chlorine solution flow rate). To function the double membrane pump (chlorine pump) in adding chlorine solution to raw water by setting the switch discharge control button to enlarge (up arrow) and reduce the chlorine solution flow rate (down arrow) as needed according to the results of calculations on mechanical devices control box. In this study, 50 lt/day (35 ml/minute) is required for the raw water discharge to be 1.5 lt/s and the residual chlorine can be seen in graph 2 above. Observing the discharge control display to find out whether the chlorine pump is in the on or off position, which is indicated by the red LED on and off which shows the discharge number that comes out through the inlet (hose). It should also be noted that the inlet hose connection of the Membrane submersible pump with the chlorine solution drum should not be folded so that the flow can function normally.

The chlorine pump in distributing the chlorine solution with a predetermined discharge continuously in the source water flowing in the reservoir 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 should not be 0 ppm [4]

Residual Chlorine in the Reservoir and the Parcel Pipeline Network

Figure 2 shows that the residual chlorine is good from dripping on the reservoir (0 km), the pipeline network is 0.5 km; 1 km; 1.5 km and 2 km varied between 0.20 to 0.7 ppm. (comply with *Permenkes RI 492/2010* concerning: Requirements for drinking water quality (Chlor residual) <7 ppm) [4]. In this study, the chlorine solution was dripped through a double membrane pump with a measured discharge (35 lt/minute) in the reservoir, the water would flow through the network pipe to the consumer. During the journey, a mixture of chlorine solution and raw water occurs and the disinfection process takes place until there is no bacteria which is indicated by residual chlorine in the raw water. The distance of water distribution from the reservoir to the customer affects the decrease in residual chlorine in the consumer. The residual chlorine was checked twice and then averaged. In the reservoir the remaining chlorine (0.7 ppm) but after being distributed 2 km m decreased to the lowest 0.2 ppm. This is due to the distance required for water to reach the consumer. There is a water disinfection reaction in the distribution in the piping network. The longer the water is in the distribution, the risk of decreasing water quality in the distribution system. This reaction will continue and the water undergoes chemical, physical and biological reactions that can change the quality of the water. The quality of the chlorine solution greatly determines the residual chlorine in the pipeline to destroy MPN coli (figure 5). There are indications that the farther the distance at the beginning of the drop to the piping network, the lower the residual chlorine in the water. This happens because during the journey the remaining chlorine is used to destroy MPN coli. The water in the pipe network farthest from the reservoir shows a residual chlorine value of 0.2 mg/l, and the low pressure in this pipe also causes a decrease in chlorine levels. 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. By dripping a stable chlorine solution with a chlorinator, the water discharge in the reservoir

varies and the number of bacteria will have an impact on the remaining chlorine in the water.
In line with the research of Sofia, E. Riduan, R. and Abdi, C. that the residual chlorine concentration in the tissue is affected by the injection of the concentration of the chlorine solution at the beginning of the distribution and the distance from the reservoir. The reduction in the concentration of free chlorine occurs due to residual chlorine reacting with the components in the water. The decrease in residual chlorine concentration can be caused by organic conditions in the water, the more organic matter, the faster the chlorine will be lost. Conditions of residual free chlorine in the distribution network exceeding 0.5 mg/l can have a carcinogenic and toxic impact [10]. Residual chlorine kills bacteria during distribution of water to consumers. The residual chlorine content is influenced by various factors such as temperature, pH, pipe conditions and sanitation in the piping and reservoir environmental. The residual chlorine content below the quality standard results in high bacterial numbers. This is in line with the research of M. Noor, Z. et al. that there is a relationship between residual chlorine levels and Coliform [11]. The use of chlorine for water disinfection is not only familiar to the community but also cheap, affordable and easy to use. Chlorine has the power of disinfection a few hours after application from the reservoir to the pipeline to the consumer. Disinfection using a solution of chlorine in water with residual chlorine (0.28-0.56 ppm) is able to destroy e coli bacteria. The remaining chlorine in the tissue is less than this concentration can result in reduced disinfectant ability so that the number of pathogenic microorganisms increases [9]. In the use of chlorine powder, the chlorine distribution line is easily clogged, corrosive to the submersible pump. The remaining chlorine in the source water flows further, the residual chlorine content will decrease along with the effectiveness of the desinfectan [13]. The presence of residual chlorine in the water indicates the loss pathogenic bacteria such as coliform, E coli. With a contact time of 10 minutes, the nature of chlorine as a disinfectant is able to reduce the number of E coli bacteria drastically and even up to 40 minutes of contact. However, the disinfectant ability will decrease as the remaining chlorine decreases [17]. This is confirmed by the research of Rahayu, Puji and Sugito that residual chlorine from 0.2 to 0.5 ppm can kill bacteria in true HIPPAM Tirto Gresik Regency Coliform bacteria appeared as much as 2.2 per 100 ml at 0.03 ppm residual chlorine condition in customer and reservation distribution lines oir PDAM Medini Kudus coliform free [11]
The addition of chlorine using a chlorine diffuser in the Pelindo reservoir shows that the difference between Total Coliform and E. coli is influenced by the level of residual chlorine in addition to the need for fluctuating water [18]. There are indications that the longer the water stays, the greater the number of bacteria when the remaining chlorine is only 0. ,2 mg/l [19]. Meanwhile, according to Tiwari et al. that sodium hypochlorite (NaOCl) has a higher effectiveness than 70 percent ethanol [20] Concentration of 1% NaOCl solution can be used as a disinfectant and even kills up to bacterial biofilms. This is different from an ethanol solution which contains at least 70% ethanol to be used as a disinfectant. In addition, the disinfection process can also use a solution containing 10% formaldehyde, ammonium disinfectant, detergent and acid.

pH measurement
The use of a chlorinator in Figure 3. shows the results of the average pH measurement at 0 km, 0.5 km, 1 km, 1.5 km and 2 km ranging from (6.7 to 7.2 ppm) that meet the requirements for drinking water [4]. The decrease in residual chlorine in the piping network (0 – 2 km) was not affected by normal 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. There are indications at the beginning of the disinfection (0 km) the pH is lower than the further the pH distribution increases. The slightest difference in pH in the water is possible due to the use of PVC (polyvinylchloride) pipes. According to Nusa Idaman Said: disinfection with chlorine compounds, pH will control the amount of HOCl (hypochloric acid) and OCl- (hypochlorite) in HOCl solution 80 times more effective than OCl- for E.Coli [21]. During the disinfection process with chlorine, pH become acidic because chlorine has acidic properties. The more chlorine is added, the lower the pH will be. Inactivation of bacteria, viruses and protozoan cysts is generally more effective at high pH [22]. The residual chlorine content is influenced by various factors such as temperature, pH, pipe conditions and sanitation in the piping and reservoir environment. Examination of residual chlorine 0.479 mg/l with a pH of 7.27 and residual chlorine 0.142 mg/l with a pH value of 8.12 means that the variation in pH value is related to the working power of chlorine in water. The higher the pH value in drinking water, the residual chlorine content will decrease. There is a strong relationship between pH and residual chlorine in drinking water In line with research by Asrydin, Crystianingsih, Juliana, Soedarjo, residual chlorine will decrease as the value increases. pH with the results of the examination of residual chlorine of 0.45 mg/l at a pH of 7.674 to 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. The higher the pH of the

distribution water, the lower the residual chlorine value [23].

Temperature Measurement

From Figure 4. the results of the average temperature measurement at a distance of 0 to 2 km range from 24.50 to 26.0°C. Based on Permenkes 492/2010 the temperature still meets the requirements[4]. At a small temperature difference and cold (25°C) showed a small difference in residual chlorine in raw water (0.20 to 0.7 ppm). The higher the temperature in drinking water, the longer the distance from the reservoir to the distribution will be able to reduce the residual chlorine content. At the residual chlorine concentration of 0.2, MPN coli still appeared in the sample water even though it was small. The concentration of residual chlorine is also influenced by the amount of MPN coli in during distribution. According to Afrianita, R. Komala, PS, Andriani, Y.: temperature values ranging from 27.5-29 C have a correlation between temperature and residual chlorine of -0.52 which indicates that temperature and residual chlorine have a moderate level of relationship, meaning that the temperature also affect the presence of residual chlorine levels in the distribution network of drinking water. The higher the temperature value in drinking water, the residual chlorine content will decrease. The increase in temperature is only 0.5ºC with a decrease in residual chlorine of 0.24 mg/l. The increase in temperature is only 0.5ºC with a decrease in residual chlorine of 0.24 mg/l. While the results of temperature measurements range from 28.8-34.9°C, it shows that the higher the temperature, the faster the chlorine decays so that the remaining chlorine is faster. finished. E coli grows at temperatures between 10-40°C with an optimum temperature of 37°C. Bacteria are very sensitive to heat [18] In line with this opinion [24]. who concluded that chlorine decays faster with longer heating. This difference in results can be caused by several conditions, such as measurements using a thermometer with low accuracy and the condition of the piping in the sampling location. Likewise with the research of Asrydin, Crystianingsih, Juliana, Soedarjo. that based on the results of the inspection the piped water temperature increased in the distribution network by 0.6ºC in the remaining chlorine 0.45 mg/l to 0.0975 mg/l [23].

Smell and Taste

The residual chlorine content (0.6-0.8 ppm) at 0-0.5 km point of adding chlorine shows a slight smell of chlorine. The appearance of the smell of chlorine can affect the uncomfortable taste for customers who consume it. 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 [4]. For chlorine concentrations below 0.5 ppm, at a distance of 1 -1.5 km it does not cause odor. There are indications that the farther the distance from the reservoir at the point of affixing the raw water chlorine solution, the less odor and the lower the concentration of residual chlorine in the water. The presence of chlorine odor in raw water indicates the absence of MPN coli. The results of research by Sofia, E. Riduan, R. and Abdi, C. that residual chlorine is 1.24 mg/l makes the water smelly, gummy and often itchy when bathing with the water. This may be due to the residual value of chlorine. high enough. The effects that occur when residual chlorine exceeds the threshold include respiratory problems in the form of bronchial reactivity (hyperresponsiveness), inflammation, coughing, difficulty breathing, shortness of breath, and reduced lung function, as well as effects that will appear on chlorine gas released from Inhaled (inhaled) hypochlorite solution is irritation of the nasal cavity and sore throat [10]. In line with Wiwin Anggraini, Rony Riduan and Mhlor Muhammad F, that high residual chlorine values, ie > 0.5 mg/l, can be toxic and carcinogenic. for customers who consume it, it can accelerate the corrosion of pipes, as well as 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 does not meet the quality standards set for drinking water. Chloramine with a concentration of 0.8 mg/lt in drinking water causes odor and causes hemolytic anemia in renal hemodialysis patients, but does not occur in animals or humans who consume chloramine by mouth. Although chloramine causes changes in bacteria and causes skin damage in mice, studies have shown that potential carcinogenic properties have not been found [21]

MPN Coli

Studying Figure 5: The mpn coli content appears in 20% of the samples at a distance of 2 km at a residual chlorine concentration of 0.20 ppm, while at a distance of 0 km and 1.5 km there are no bacteria because the residual chlorine ranges from 0.3 to 0.8 ppm). This shows that the residual chlorine in the water is more than 0.3 ppm free of MPN coli but the residual chlorine should not be more than 0.7 ppm and MPN coli should not be more than 50/100 ml of the sample [4]. The content of mpn coli (0/100 ml of sample water) meets the standard requirements for drinking water and in this study, 2/100 ml of sample was found at a distance of 2 km, the remaining chlorine was 0.2 ppm. There are indications that the residual chlorine in the raw water flows further will make the residual chlorine content will decrease along with the effectiveness of the disinfectant will decrease. A residual chlorine value of at least 0.2 mg/l is needed to ensure that certain pathogenic microorganisms have died and can prevent certain pathogenic microorganisms from living as long as the water is in the pipe network, if the residual chlorine value is <0.2 mg/l it causes water quality to be guaranteed. drinking from contamination by pathogenic microorganisms. However, a high residual chlorine value of >0.5 mg/l can cause a chlorine odor and taste that is uncomfortable, toxic and carcinogenic to customers who consume it. Disinfectant concentration, detention time, temperature, pH, and water quality greatly affect the content of MPN coli in water. According to Noor Zahrotul M, Nurjazuli, Trijoko, the residual chlorine content of 0.03 ppm in the reservoir and distribution pipelines is still relative to the number of MPN Coliforms. Variations in the number of Total Coliform and E. coli in the sample water are not only influenced by the effectiveness of disinfection but also by the continuous flow of water and the effect of leakage in the pipe, resulting in the entry of contaminants from the pollutant source [11]. Disinfectant using chlorine at a dose of 0.457 mg/l with contact time for 30 minutes, then tested for E. coli bacteria in the distribution network (the area with the lowest residual chlorine), no Escherichia coli bacteria were found in the water. To ensure the water consumed is free from total coliform and e. coli, the use of chlorine in the disinfection process must use the calculation of the right dose, chlorine absorbency (DPC), safety value or residual chlorine that is expected according to quality standards [18]. When the residual chlorine is only 0.2 mg/l the disinfection ability decreases and will make the number of bacteria more and more [19]. Chlorine diffuser as a method of reducing total coliform requires a chlorine dose of 3.5 mg/l to a dose of 4 mg/l with an application time of 30 minutes to 60 minutes of monitoring [26].

2. Conclusion

Performance of chlorinator: double membrane pump discharge: 50 lt/hr at source water discharge 1.5 lt/s Chlorine requirement of 93 gr/day obtained results: residual chlorine at a distance of 0 m, 0.5 km, 1 km, 1.5 km and 2 km respectively: 0.68 ppm 0.53 ppm, 0.45 ppm; 0.41 ppm and 0.29 ppm, complying with the Minister of Health Regulation No. 492, 2010 is a need for further research on this chlorinator tool for AC current and for disinfecting liquid waste both industrial and household so as to produce adequate efficiency and performance and have a selling value.

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