

# Water Treatment Using Plasma Generated by High Voltage Tesla Transformer to Eliminate Escherichia Coli Bacteria

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**Abstract**—Availability of a healthy consumable water decrease during time. This is mainly due to the presence of pollutants which degrade the ground water quality. Many of the pollutant sources are produced by human activities such as household wastes. Other main pollutant sources are agricultural and industrial wastes. One of the most concerns regard the drinking water quality is the presence of the pathogenic microorganism such as Escherichia coli. If consumed, Escherichia coli can cause diarrhea which could lead to severe stomach ache. Many approaches can be applied to disinfect the drinking water to eliminate the Escherichia coli. In this paper, discussed water treatment by using plasma generated by tesla transformer to disinfect the water thus eliminate the Escherichia coli. A prototype of the water treatment system is built by using a Tesla transformer to produce high voltage thus generate plasma which then used to kill the Escherichia coli bacteria. It is found that the system is able to eliminate the Escherichia coli bacteria when the water is treated for 60 minutes. The water quality is not affected by the treatment process. The water pH is in the range of 6.5-8.5, which is still meet the standard. Water TDS is slightly increase, but also still in the range acceptable i.e. below 500 ppm.

**Keywords**— water treatment, plasma, Tesla transformer, High voltage, Escherichia Coli

## I. INTRODUCTION

A safe and healthy drinking water is one of the mayor need for the human living. The drinking water must be free from pathogenic microorganism contaminants which are very dangerous for human health [1,2]. If consume, those contaminants can cause health problem. Consuming contaminated water can cause various diseases, especially digestive diseases. Indonesian health minister predicts there are more than 7.2 million people have diarrhea due to the poor water sanitation [3]. So, it is very important to provide healthy drinking water which is free from pathogenic microorganism.

Healthy drinking water can be produced by processing the contaminated water using several methods. Perhaps, the most popular and cheapest method to eliminate pathogenic contaminant is using chlorine [4]. However, using chlorine for a long period of time can cause environmental hazard and also degrade human health [5], thus different material needs to develop as a substitution for the chlorine. Ozone as disinfectant to eliminate pathogenic microorganism is gain popularity and slowly replace the using of the cholerine [5]. Even though ozone relatively harmless to apply in process drinking water disinfect, however the ozone has much lower capability to eliminate pathogenic microorganism in water. Because the ozone is easily to solute in water thus its disinfectant effect is very low [6,7].

Many methods then developed to replace chlorine and ozone as water disinfectant. In [8], developed a system for water treatment using plasma as disinfect. Plasma has mayor advantage over chlorine and ozone, as it is not need any substance addition during the water treatment process [9,10].

Plasma can be produced by varying electric discharge methods. Plasma can be classified into two categorical based on the electric density, pressure and temperature, i.e. cold plasma and hot plasma [11]. Cold plasma is obtained in low pressure or in short pulse discharges as dielectric barrier discharges. The collision rate between electrons and gas molecules is not sufficient to build non-thermal equilibrium plasma. Whilst hot plasma is produced in high pressure discharges. The collision rate between electron and surrounding gas is high enough to sustain the non-thermal equilibrium between the electron and heavy particles [12].

In the research conducted by Akan et al [13], hot plasma is used to eliminate microorganism in water. Microorganism is eliminated as a combine effect of the produced gas and UV light generated by the plasma. Plasma discharge produce several gas i.e. OH, O, O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub>, NO which able to disinfect water. Beside the gas, plasma is also produce UV light which able to kill microorganism in the water [14]. Plasma is also generated electric field which help to kill microorganism [15]. Plasma discharge can be produced by using varying method such as dielectric barrier discharge, corona discharge and spark discharge [16].

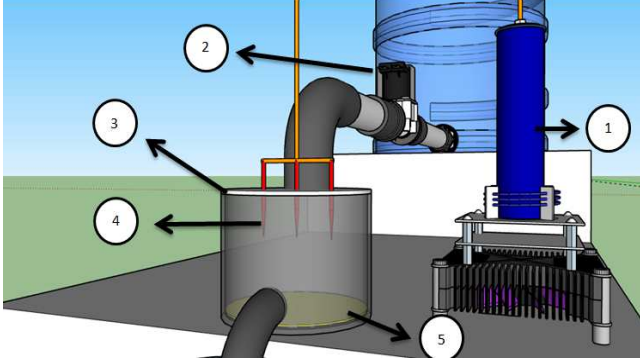
In [17] discussed the used of cold plasma which generated by spark discharge and injected to the water surface to kill Escherichia coli bacteria. Ther results show the bacteria number decrease by factor 5-log for every 20 minutes. It is also found that the plasma in water produce hydrogen peroxide which help reduce the bacteria number.

Water treatment by using cold plasma is also discussed in [6]. Using cold plasma for 16 minutes is proven effective to eliminate Staphylococcus aureus bacteria from the water sample. In their research, it is also found that the plasma produces perhydroxyl radical (HOO) which cause the pH decreasing. The perhydroxyl radical oxide is also able to reduce the Staphylococcus aureus bacteria.

In this paper discussed the use of cold plasma generated by a mini-Tesla transformer to eliminate the Escherichia coli bacteria in water. The mini-Tesla transformer generates electric discharge which is used to disinfect the water. The input voltage of the tesla coil is set to 220 volts. Thus, it is possible to applied as a water treatment system for household application.

## II. EXPERIMENT SETUP

Figure 1 shows the diagram of the water treatment experiment conducted in the laboratory. The main component are mini-Tesla transformer and the water chamber. The mini-Tesla transformer generates electric discharge which then produce plasma. The water chamber is used as the water treatment chamber. A water container is used to store water which use to fill the water chamber.



Noted : 1. Mini-Tesla transformer, 2. Water tank, 3. Water tank, 4. needle electrode, 5. ground plate.

Fig. 1. Experiment diagram of the water treatment process

### A. Mini-Tesla transformer

Mini-Tesla transformer use air as the core to induct energy from primary into secondary coil using a very high frequency. Thus, Tesla transformer able to generate a very high frequency due to resonance of the energy transfer between the two coils. The input voltage on the primary coil is set to low voltage 220 volts. The output generated by the secondary coil generated high voltage which able to produce electric discharge thus generate plasma. Figure 2 shows the mini-Tesla transformer use in the experiment. The primary coil use copper wire with diameter of 1 mm. The coil length is 7 mm and its diameter is 40 mm. The secondary coil is use copper wire with diameter of 0.25 mm. The secondary coil height is 90 mm and its diameter 26 mm. The triggering switch is an electronic type thus have a very precise switching time.

### B. Water Chamber

The plasma generated by the mini-Tesla transformer then injected into the water chamber for the water treatment process. The electric discharge above the water level will produce ozone, ion, UV light, photon and metastable [14]. The discharge on the water surface is also produce short radicals such as hydroxyl-radical (OH), and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) which also act as disinfectant agent [14].

Figure 3 shows water chamber use in the experiment. Water chamber is a circular tube with diameter 8 cm and height 12 cm. The input volage is the mini-Tesla generator output. The input voltage then distributed by using 3 needle electrodes. So, the electric discharge can be distributed on the water surface more evenly. The needle distance is set around 0.5 cm above the water level. Setting the needle to close or contact the water surface will cause the plasma failed to generate. A grounding plate installed at the bottom of the water chamber. This grounding plate is needed to ensure that the electric discharge will flow through the water. This is also to prevent the electric discharge leaked to the outer box of the water treatment system, thus avoided any electric hazard to the user.



Fig. 2. Tesla Transformer used in experiment

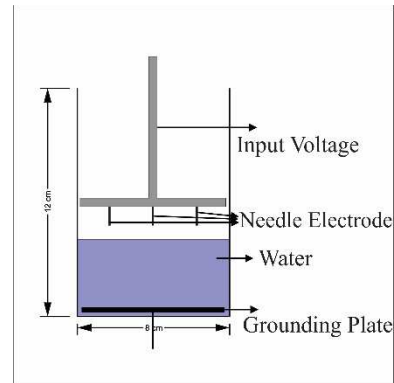


Fig. 3. A circular tube water chamber diagram

## III. RESULTS AND DISCUSSION

The water sample in this research was taken from public water. The water well is use by surrounding resident for daily needs. The water is tested in laboratory to measure the pH and TDS and the presence of the Escherichia coli bacteria.

### A. Water source quality

Table I shows the test result of the water taken from the water well. The water is untreated and tested as it is. From Table I, it can be seen the Escherichia coli bacteria content is above the standard value for water drinking. The pH and TDS of the water sample are still meet the water drinking quality.

TABLE I. WATER QUALITY OF THE WATER WELL SAMPLE

Parameter	unit	Test value	Quality Standard
Ph			6.5-8.5
Temperature	°C	29	27.5
TDS	ppm	0.146	500
MPN coli	/100ml	1600	0
form			

### B. Water Treatment

The water sample taken from the water well then treated using the prototype of the water treatment system. Figure 4 shows typical plasma produce during the experiment. The plasma can be seen just above the water, below the three needles. The water sample divided into 9 samples and divided into 3 groups based on the water volume 100, 200 and 300 ml. The water samples are treated using the water treatment system. Each samples in the 3 group treated for 1, 10 and 60 minutes to find the effectiveness of the water treatment system. Table II shows the water quality after water treatment is conducted.

TABLE II. WATER TREATMENT TEST RESULT

No	V (ml)	T (minutes)	TDS (PPM)	pH	E-Coli (MPN/100ml)
1	100	1	0.147	7.9	4
2	100	10	0.160	7.8	0
3	100	60	0.189	7.7	0
4	200	1	0.147	7.8	7
5	200	10	0.150	7.7	3
6	200	60	0.159	7.6	0
7	300	1	0.147	7.7	9
8	300	10	0.155	7.6	5
9	300	60	0.161	7.4	0



Fig. 4. Typical plasma generated during water treatment process

### C. Effect of duration water treatment to water pH

Based on Table 2 data, the effect of the duration water treatment for water pH value is shown in Figure 5. For the three groups volume of water sample, the pH decrease as the duration of the water treatment increased. The highest drop occurs for the less volume water. The water pH for all samples are still meet the quality standard of the drinking water.

The water pH drops even when the water was treated for just 1 minute. Perhaps, this is due to the gas produced by reaction of the plasma with the water, where several kinds of gas produced such as OH, O, O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub>, NO [13]. These gases tend to decrease the water pH [6].

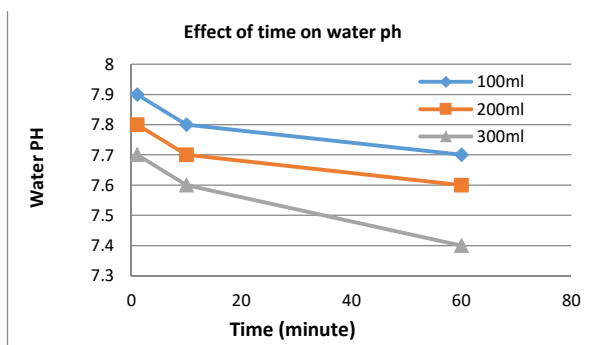


Fig. 5. Effect of duration water treatment on water pH for varying water volume

### D. Effect of duration water treatment on Total Dissolved Solid (TDS) of the water

The water treatment using plasma in this research produce a solid material due to electric discharge on water surface. The coagulation occurs as the react of electric discharge, air and the water. The coagulation volume increase if water treatment process take longer period of time. Sample with less volume has higher TDS after the water treatment process. Perhaps it is due to the water temperature is higher for the sample with less water volume, so the coagulation is easier to occur. Nevertheless, as the TDS value of the water sample increase just up to 0.19 ppm, the water quality still meet the quality standard. The water quality standard noted that the TDS on water drinking should less than 500ppm [17]. The total dissolved solid (TDS) of the water after treated for varying time is shown in Figure 6.

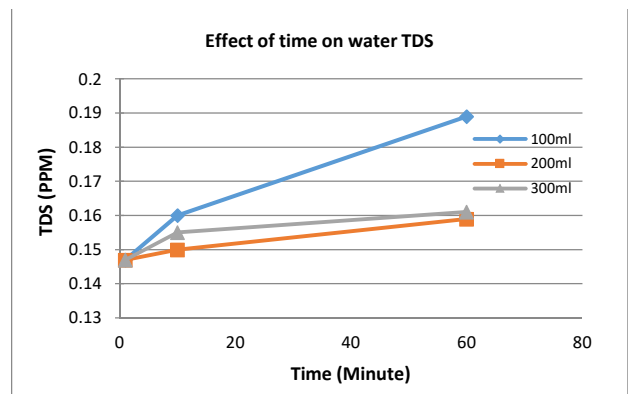


Fig. 6. Effect of duration water treatment on Total Dissolved Solid of the water

### E. Water treatment to eliminate Escherichia coli bacteria

The efficiency of the water treatment system to eliminate the Escherichia coli bacteria is shown in figure 7. The water treatment system shows ability to eliminate the presence of Escherichia coli bacteria. For all three groups water volume, Escherichia coli bacteria is eliminated when the water is treated for 60 minutes. For water volume of 100 ml, the water treatment system able to eliminate the bacteria after treated for just 10 minutes. When treated for 10 minutes, the water samples 200 and 300 ml still contain bacteria although the bacteria number reduced significantly. The above results show the water treatment system, using mini-Telsa transformer, has ability to eliminate the pathogenic bacteria. Although the time needed to eliminate the bacteria is quite long. Perhaps, the time process to eliminate the bacteria can be reduced by using larger power Tesla transformer.

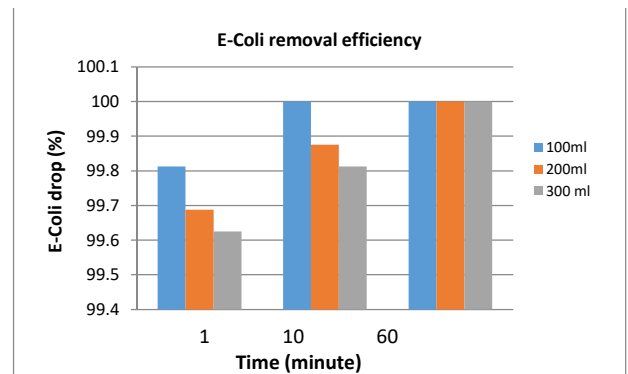


Fig. 7. The effectiveness of the water treatment system to eliminate the Escherichia coli bacteria

#### IV. CONCLUSION

The healthy drinking water must not contain any pathogenic microorganism such as *Escherichia coli* as it can cause severe diarrhea. In this research, discussed the using of plasma produce by mini-Tesla transformer to reduce or even eliminate the presence of *Escherichia coli*. The result shows that the system is able to eliminate the *Escherichia coli* bacteria when the water is treated for 60 minutes. The water quality is not affected by the treatment process. The water pH is in the range of 6.5-8.5, which is still meet the quality standard. Water TDS is slightly increase, but also still in the acceptable range i.e. below 500 ppm.

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