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Plasma Generator Design For Citarum River Water Purification and Sterilization After Initial Filterization

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Abstract: Mountain water is the main raw material in drinking water depots and water from drinking water companies is known as healthy water and good for consumption, people think this water is the best, while the population, costs increase every year, and transportation terrain is increasingly difficult, how long can this condition last. River water and soil that are properly processed, namely filtration and ozone disinfection, can be a substitute for mountain water, by designing, creating, and implementing appropriate technology to process river water and soil so that it is suitable for consumption. Plasma Generator is a tool for producing Ozone, which is used as a strong disinfectant and without residue in water. This tool uses a spiral cylinder electrode method with Dielectric Barrier Discharge (DBD). Corona release occurs between high voltage electrodes of 13.28 kV from a distance between electrodes of 0.5 mm, capable of producing ozone that can purify dirty water and sterilize water containing E. coli bacteria.d

Keywords: Plasma Generator, Citarum River, Sterilization, Corona, High Voltage

INTRODUCTION

Water use has increased by about 500% over the last century, mainly as a result of population growth and economic development. Currently, global water demand is estimated at about 4600 km3 per year, a number that is expected to increase in the coming decades as shown in Figure 1. The world population is expected to increase from 7,700 million (7.7 billion) in 2017 to between 9,400 (9.4 billion) and 10,200 million (10.2 billion) in 2050, a fact that involves increasing water needs related to food and energy production, in addition to domestic needs. In addition, increasing industrialization and the provision of water supply services in developing regions of Africa, Asia and South America contribute significantly to this inevitable growth in water demand (Cruz, 2020)

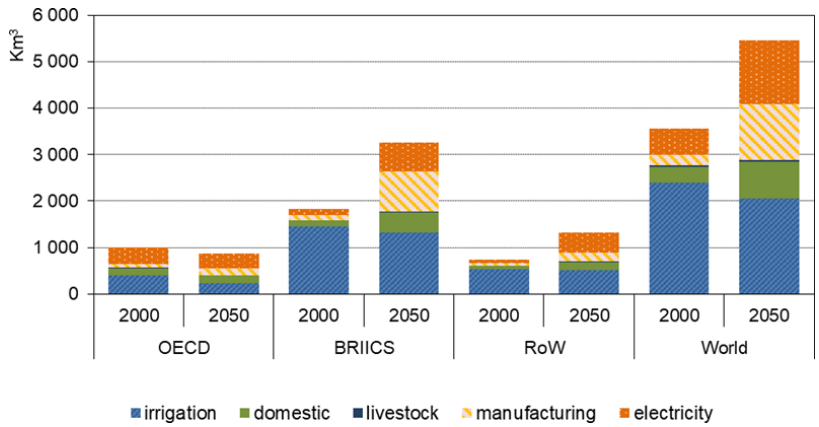

Figure 1. Global water demand (fresh water) in 2000 and 2050 (projections based on 2000 data)

Only 2.5% of the 71% of water covering the earth's surface is fresh water, and only 1.2% of that amount is a resource available to humans. The world's freshwater resources are renewed through a continuous cycle of evaporation, precipitation, and runoff. Figure 2. can be useful as an initial estimate of the availability of freshwater resources in certain regions of the world (Cruz, 2020).

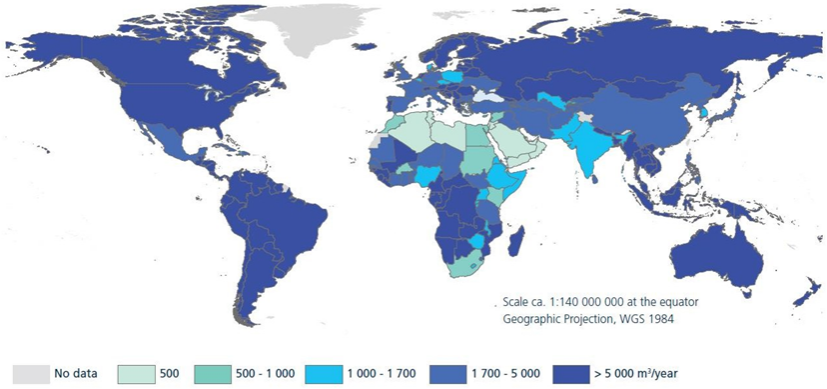

Figure 2. Total renewable fresh water (m³ per capita per year) in 2014.

Based on this indicator, various levels of water scarcity in a region with a renewable water level between 1700 and 5000 m³ of water per capita per year can experience water shortages that occur in the region. With less than 1700 m³ of water per capita per year, a country is considered to be experiencing normal water scarcity, while a region is in chronic and absolute scarcity when renewable water per capita per year falls below 1000 m³ and 500 m³, respectively.

Environmental pollution is increasing and complex, including water pollution from industry and households. The need for clean water suitable for consumption is increasing while water sources are starting to decrease along with the reduction in infiltration water. We cannot only rely on mountain water which has a safe water reserve during the rainy season, on the other hand during the dry season it is insufficient or even lacking. Large rivers such as the Citarum River still have quite abundant water, but the problem is that the water is cloudy and polluted by arsenic (Rusmana и съавт., 2019).

To overcome environmental pollution problems by designing, creating, and implementing appropriate technology to create an ozone reactor with plasma technology or high-voltage corona discharge. While ozone is a gas that is naturally found in the earth's atmosphere, has a pungent odor, is a strong oxidizer, and is a disinfectant. Determining the ozone content produced by the reactor is very important (Triandini, 2024). The amount of

plasma produced is influenced by the high voltage source, type and shape, and distance of the electrodes used in the Ozone reactor.

With a high voltage impulse generator using a flyback converter, a high voltage impulse will be obtained. In addition, by adjusting the electrode configuration in the Ozone reactor, a corona discharge can be obtained, so that more plasma and Ozone are produced (Physics и съавт., 2022). The amount of plasma and ozone formed at the same time can be used for example to eliminate unpleasant odors in rooms and cars, purification and sterilization of unfit water. The ozone produced is expected to help producers and households in the processing of drinking water or water for fish ponds and hydroponic cultures, even for wastewater purification (Sari и съавт., 2023). This journal will discuss the ozone generation system using plasma dielectric barrier discharge (DBD) and a plasma reactor built with a coaxial electrode geometry configuration (spiral-cylinder) by adding a dielectric barrier layer, namely pyrex glass, can remove corona. Then discuss the results of the ozone generator, whether it meets the standards and is capable of being a strong oxidizer in water or not. Is the ozone generator suitable for use as a purifier and sterilizer of Citarum river water with initial filtration so that it is synchronized for households and bottled drinking water business actors.

METHOD

Research purposes

1. The aim of this research is to remove corona from a plasma generator in a reactor, and by blowing dry air, ozone is produced which can be a disinfectant for drinking water.
2. Providing Ozone generating equipment does not have to be imported, for drinking water and household businesses.

Types and Flow of Research

This research is an experiment of a power supply multiplier generator with a reactor to produce corona discharge, where the flow diagram of the research is shown in Figure 2.1.

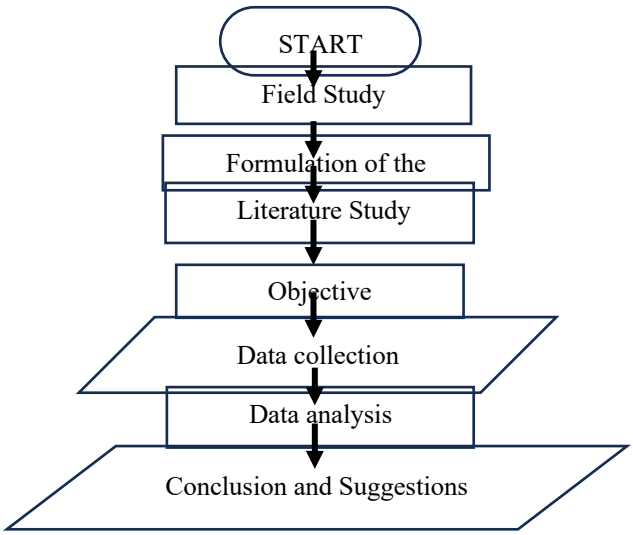

Figure 3. Research Flow

This research is an experiment of a power supply multiplier generator with a reactor to produce corona discharge, where the flow diagram of the research is shown in Figure 3.
Prinsip kerja Generator Plasma seperti di gambar 4. :

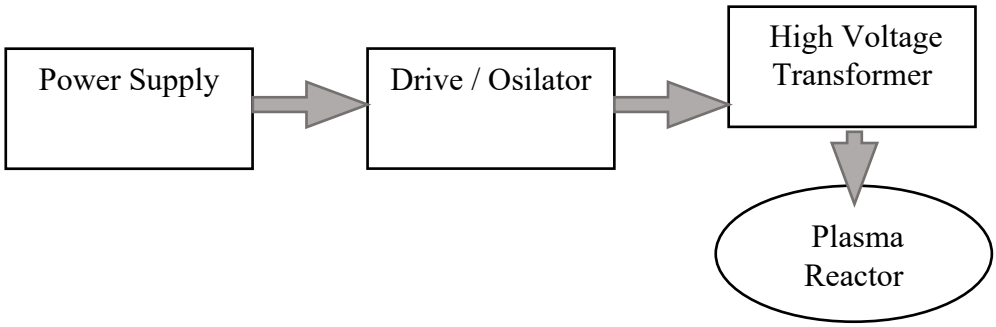

Figure 4. Working Principle of Electronic Circuits

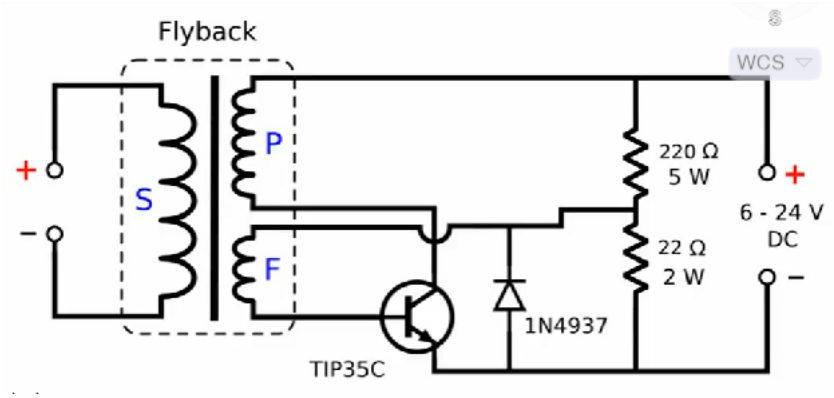

Figure 5. Voltage Generator Wiring

Figure 5. is the wiring of the flyback driver with a transistor as a current controller through the primary coil of the flyback. This circuit works on the principle of fast switching of the NPN transistor controlled by feedback from the feedback coil. So without this feedback coil, the transistor will not turn off automatically, so that oscillation will not occur and will not flow high voltage. When the transistor turns off, the energy stored in the flyback core is released to the secondary coil, producing high voltage.

Figure 6. is a schematic of a plasma generator, where the ozone produced is sucked by the flow through the Venturi.

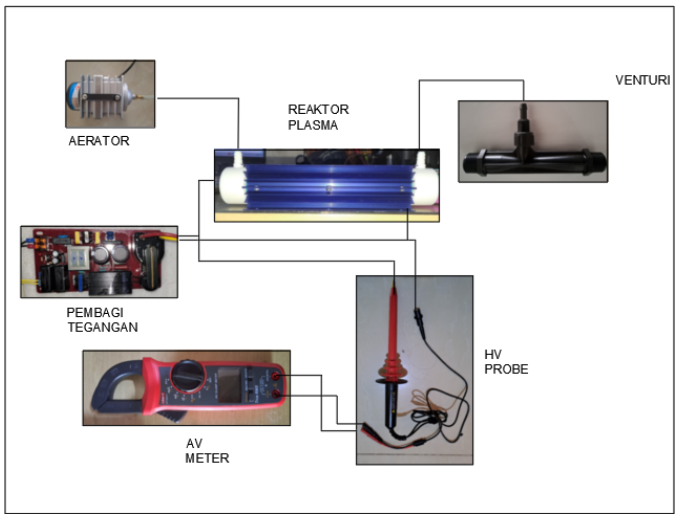

Figure 6. Schematic of Ozone Generation System

RESULT AND DISCUSSION

Testing and analysis equipment includes high voltage measurements and drinking water treatment applications with corona discharge plasma technology.

Power Measurement

The power required by this tool can be calculated using equation (2.4), namely:

$$P = I \cdot V \cdot \cos \theta$$

Based on the measurements on the tool (figure 4.1), the current obtained is 0.588 A, the PLN electricity voltage is 224 V, cos θ is 0.9 and the power required is 122 watts.
Proven by the formula,
P = 0,588 . 224 . 0,93 = 122 Watt.

Figure 7. Electronic Meter

High output voltage measurements cannot be directly measured using measuring instruments such as multimeters (AV meters), this can damage the measuring instrument, therefore a retaining device is needed so that it can be read on the AV meter, namely using 40 kV HV Probe with a voltage division ratio of 1: 100.

Output High Voltage Measurement

Dry air is blown through an air bubbler or aerator stone into the test water, obtaining a result of 132.8 X 100 = 13,280 V (13.28 kV) as shown in Figure 6. A light violet light appears and a very pungent ozone odor is detected, indicating that both electrodes have discharged plasma.
Plasma is characterized by the emergence of light violet light around the surface of the conducting wire accompanied by a hissing sound and the smell of ozone (Aditia, 2021).

Figure 8. High voltage measurement with a frequency of 100 Hz.

The third measurement test (with a high output voltage of 13.2 kV) which is used for the next test is testing with dirty clean water and testing the activation of ecoli bacteria and other pollutants.

Ozone level testing

Citarum water after being blown with high voltage ozone gas output of 13.2 kV frequency of 100 kHz was tested for ozone levels in water, where the water tested was 1 gallon (19 liters) for 30 minutes. The ozonation and measurement process with an Ozone meter, as in Figure 4.4 (a) and (b).

(a) (b) (c)

Figure 9. Ozonation Process and Ozone Level Measurement
(a). Ozonation Process
(b). Ozone Level Measurement
(c). Enlarged Measurement

Based on **SNI 01-3553-2015**, after the ozonation process, the ozone content in water is 0.05 – 0.3 ppm, as seen in Figure 9. (c), it can be seen that the ozonation results with an ozone content of 0.3 ppm are within the standard.

Testing with contaminated clean water

This test uses 350 mL of clean water, which is stained with red crepe paper where the red color is soluble in water.

(a)

(b)

Figure 10. Clean water (a) and polluted water (b) before ozonation.

(a). Citarum River Water 350 ml
(b). The Water Was Littered With Thick Red Crepe Paper

(c)

(d)

Figure 11. After 5 Minutes (3) and 10 Minutes (4) Ozonation
(c). After 2 Minutes Ozonation
(d). After 7 Minutes Ozonation

From the test results, ozone gas is flowed into a test glass containing contaminated water (figure 10.), with a time of 2 minutes the color begins to fade as in figure 11. (c) and when continued for 5 minutes so the total ozonation time is 7 minutes, the water looks clear again as before as in figure 4.6 (d). The ozone generator uses electricity, so it needs to provide 122 VA of electricity. The need for a cooling and insulation system because Ozone is a reactive gas, so the generator must be designed with corrosion-resistant materials and an efficient cooling system to prevent overheating. Reduction of Chemical Emissions, with the use of ozone, several industries reduce hazardous chemical waste (Ryane и съавт., 2013). New market opportunities, increasing awareness of sanitation and waste management create business opportunities for ozone generator manufacturers.

Microbiological laboratory tests on Citarum water before ozone disinfection.

Testing was carried out on Citarum river water that had undergone initial filtration (with alum, silica sand and activated carbon).

Organoleptic Analysis

The initial analysis is organoleptic analysis, namely a testing method carried out using human senses (sight, smell, taste, touch, and hearing) to assess the characteristics of a product, especially in the food, beverage, cosmetics, and pharmaceutical industries (Di & Ubp, 2018). Aspects Assessed in Organoleptic Analysis Warna, dinilai menggunakan penglihatan, menentukan apakah produk memiliki warna yang sesuai dengan standar.

1. Aroma, assessed using smell, ensures the product odor does not deviate or has the desired characteristics.

2. Taste, used for food and beverages, assessing the level of sweetness, saltiness, sourness, bitterness, or umami.
   Advantages of organoleptic analysis:
   1. Fast and simple
   2. Does not require special tools
   3. Can detect small changes in the product.

   Disadvantages of Organoleptic Analysis :
   1. Subjective (influenced by individual perception)
   2. Results may vary between individuals
   3. Requires trained individuals for accurate results.

   Where the results of the organoleptic analysis can be seen in table 4.1 below :

Table 1. Organoleptic Analysis Results

Origin of water	Smell	Taste	Color	Result
Citarum water	Odorless	No taste	Colorless	According to parameters (Minister of Health Regulation number 32 of 2017)

The results of the organoleptic test in table 4.1, Citarum river water after going through initial filtration, all meet the requirements according to the parameters that have been set. It has odorless, colorless and tasteless results.

E Coli Test Analysis

Escherichia coli (E. coli) test analysis is a method for detecting the presence of E. coli bacteria in water. E. coli is a major indicator of fecal contamination and poor sanitation (Nawan и съавт., 2023). Interpretation of the analysis results are :

- Negatif, no E. coli was detected, indicating the product or water is safe for consumption.
- Positif, E. coli was detected, indicating possible fecal contamination.

Where the results of the E Choli test analysis are as in table 4.2 below :

Tabel 2. Hasil Analisa Uji *E Coli.*

Origin of water	Analysis Results		Standard (Minister of Health Regulation Number 32 of 2017)
	Quantitative	Qualitative	
Citarum Water	4,55 (There are air bubbles in the tube durham)	Positive	<1

The results of the E. Coli test analysis in table 4.2 on Citarum River water after initial filtration showed positive results for E. coli bacteria, which was indicated by the presence of bubbles in the Durham tube in the confirmatory test, as can be seen in Figure 12.

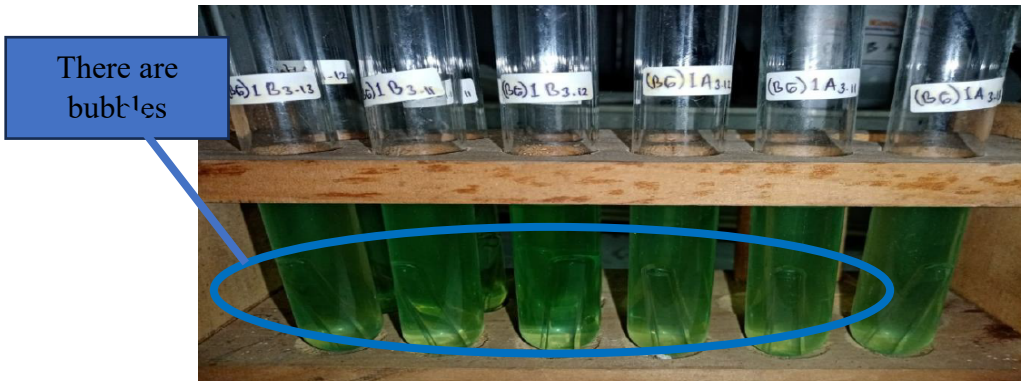

Figure 12. Confirmation Test Before Ozonation

TDS and pH Test

pH is a measure of the acidity or alkalinity of a solution, with a scale of 0-14, the pH standard according to Health Ministerial Regulation Number 32 of 2017 is 6 to 8.

TDS is the amount of dissolved solids in water, such as minerals, salts, and heavy metals. The unit of measurement is ppm (parts per million) or mg/L (Minister of Health of the Republic of Indonesia, 2017). Where water is suitable for consumption according to the Minister of Health Regulation number 32 of 2017 is a maximum of 500 ppm.

Table 3. Results of TDS and pH Analysis of Citarum Water

Origin of water	Tds	pH	Information
Citarum water	165 ppm	7,00	Meet the requirements (Minister of Health Regulation number 32 of 2017)

The results of TDS and pH analysis in table 3. using a TDS meter and pH meter on the sample meet the drinking water quality requirements.

Microbiological laboratory tests on Citarum water after disinfection with ozone

In the analysis of water tests after disinfection with ozone, the focus is on the analysis of E. Coli bacteria, where if it is still contaminated with this bacteria it can be dangerous for our health.

- Prevent diseases caused by pathogenic E. coli such as diarrhea, urinary tract infections, and food poisoning.
- Ensure food and drinking water safety.
- Meet quality standards and health regulations (Minister of Health of the Republic of Indonesia, 2017).
- In this bacterial test, in identifying microorganisms, three stages are used, namely predictive media, confirmatory media and strengthening media. The results of the test analysis can be seen in table 4.4 below :

Table 4.4 E. Coli Test Results

Origin of water	Hasil Analisis		Standard (Minister of Health Regulation number
	Quantitative	Qualitative	

			492 of 2010)
Citarum water	0	Negative	0

The results of the E. Coli test analysis as seen in table 4.4 in Citarum River water with ozonation, the results were negative, which was indicated by the confirmation test where there were no bubbles in the Durham tube, as shown in Figure 11.

Figure 13. Confirmation Test After Ozonation

Water test results before and after ozonation.

Hasil pengujian air sebelum dan sesudah pengozonan dapat dilihat pada tabel 4. dibawah ini :

Tabel 4. Resume Hasil Analisa Uji Air Citarum

Nomor	Point Analisa	Sebelum Ozon	Sesudah Ozon
1	TDS	165	165
2	pH	7	7
3	*E Coli*	4,45	0
4	Warna	Tidak Berwarna	Tidak Berwarna
5	Bau	Tidak Berbau	Tidak Berbau
6	Rasa	Tidak Berasa	Tidak Berasa

Test Path Analysis

From the test results above, a test path analysis can be made which shows the hypothesis of corona discharge, ozone and consumers (ozone users) as in figure 11 below:

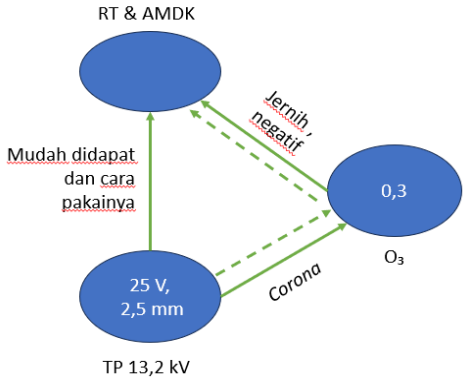

Figure 14. Test Path Analysis

CONCLUSION

Based on the results of the discussion, it can be concluded that :

The cylindrical spiral electrode method with dielectric barrier discharge (DBD) with a distance or gap between electrodes in the corona discharge tube of 0.5 mm with a high DC

output voltage of 13.28 kV, can discharge corona and when dry air is inputted at 45 LPM can produce ozone.

1. The ozone content in water after ozonation is 0.3 ppm, this is in accordance with the SNI 01-3553-2015 standard.
2. The ozone produced is then put into clean water that is polluted through a hose with an air bubbler stone tip, able to make polluted water clear as before. Citarum river water with initial filtration is suitable to be used as raw material for drinking water with a TDS of 165 ppm and a pH of 7, when mixed with ozone as a disinfectant, Ozone is able to sterilize the water from ecoli bacteria with a test result of 0 or negative. So the ozone generator that is built is a suitable Ozone producing tool and can be used for the needs of bottled drinking water businesses and households.

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