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Drinking Water Production from Rainwater Using Radio Frequency Plasma System

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Important Date

~~20th July, 2020~~ 20th August, 2020	~~27th July, 2020~~ 27th August, 2020	~~28th July, 2020~~ 28th August, 2020	~~5th – 6th August, 2020~~ 9th September, 2020
Paper submission deadline	Notification	Registration	Conference

Welcome to ESTIC 2020, Padang, Indonesia

On behalf of the organizing committee, I extend my hands to invite you to the 5th Engineering Science and Technology International Conference (ESTIC 2020).

The conference was initiated on 2011 and 2013 by the Faculty of Industrial Technology of Universitas Bung Hatta under the modest name of National Conference of Science and Technology (*Resatek*). The conference then expands and changes its name into the 3rd Engineering Science and Technology International Conference on 2016 and 2018. The conference adopted the present name and expanded its scope to international. The conference has facilitated the communication between scientists across applied in engineering technology science.

Applied Engineering technology is progressing rapidly and enables us to reveal and comprehend how this universe works. This conference will allow applied technology professionals to contribute their expertise to deal with empowerment issues. Due to COVID-19 pandemic, **the conference will be held online via Video Conference**.

This event is aimed at promoting engineering technology research activities in Indonesia and overseas, in the hope of building and strengthening networks and collaborations. The upcoming conference theme is "Applied Technology *for Sustainable Development*".The conference is open to all researchers in applied engineering technolgy. I am looking forward to meeting you in Padang, Indonesia.

With best regards,
Chairman of ESTIC 2020
Dr. Burmawi, ST, MSi

About ESTIC

The Engineering Science and Technology International Conference is a scientific meeting aimed to promote mutual exchange between scientists and also experts, to discuss

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innovative ideas in scientific research. The scope of this conference is applied research in mechanical engineering, chemical engineering, industrial engineering, electrical engineering, information engineering, civil and environmental engineering. The origin of this conference was initiated on year 2011 and 2013, by the Faculty of Industrial Technology of Universitas Bung Hatta, under the name of *Resatek or Rekayasa Science and Teknology* (national conference). The conference then expand its scope to international on 2018 and formally adopting the current name.

Poster and Oral Presentation Award

Poster and Oral award will be given by the Rector of Universitas Bung Hatta to several poster and oral presenters. The screening will be done by several expert reviewers who will walk around during the poster session. The scoring rules are as follow:

1. The score is given based on: (a) scientific content (50%), (b) presentation to audience (30%), and (c) poster design (20%);
2. Poster that is not attended by the presenter during the poster session will not be considered for the award.

NOTICE: We will be performing vital maintenance work on 5th April between 10:00am and 12:00pm (UK time) that may affect users visiting the site using their university or institutional single sign-on credentials. Please accept our apologies for any inconvenience this may cause during this time.

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Abstract

Indonesia has a large amount of rainfall and can be used as raw water of drinking water. A Radio frequencyplasma system radiation can produce active compounds (•OH^-, •O, •H^+, H_2O_2, O_3 etc) in water, the active compounds have a high oxidation potential and can kill microorganisms present in water (fecal coliform, total coliform and *Salmonella*). Plasma system is one way to produce drinking water in terms of health aspects because in the process the tool does not contact with the material directly, so the possibility of contamination is small. The purpose of this study is to remove microorganisms in rainwater using plasma radio frequency system continuously. Samples will be filtered using pure and mix polypropylene cartridge filter with a pore size of 1 μm and then contact in plasma system. Plasma is generated by applying a frequency of 0,16 MHz through a glass reactor with a thickness of 2 mm which is wrapped by a 1 mm copper wire. The results show that the removal microorganism in rainwater using plasma coupled with filtration using pure polypropylene filter reached 100% for total coliform, fecal coliform and *Salmonella*. While the removal microorganisms in rainwater using plasma coupled with filtration using mix polypropylene reached 70–100%, 85–100% and 80–100%, for total coliform, fecal coliform and *Salmonella*, respectively.

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Abstract. Indonesia has a large amount of rainfall and can be used as raw water of drinking water. A Radio frequencyplasma system radiation can produce active compounds (•OH^-, •O, •H^+, H_2O_2,O_3 etc) in water,the active compounds have a high oxidation potential and can kill microorganisms present in water (fecal coliform,total coliform and *Salmonella*). Plasma system is one way to produce drinking water in terms of health aspects because in the process the tool does not contact with the material directly, so the possibility of contamination is small. The purpose of this study is to remove microorganisms in rainwater using plasma radio frequency system continuously. Samples will be filtered using pure and mix polypropylene cartridge filter with a pore size of 1 μm and then contact in plasma system. Plasma is generated by applying a frequency of 0,16 MHz through a glass reactor with a thickness of 2 mm which is wrapped by a 1 mm copper wire. The results show that the removal microorganism in rainwater using plasma coupled with filtration using pure polypropylene filter reached 100% for total coliform, fecal coliform and *Salmonella*.While the removal microorganisms in rainwater using plasma coupled with filtration using mix polypropylene reached 70–100%, 85–100% and 80–100%, for total coliform, fecal coliform and *Salmonella*, respectively.

1. Introduction

Water is a primary need for all living things. Water is used to meet human needs, including for drinking, cooking, and washing. If the water needs have not met the drinking water standard,then it can have a major impact on health and social. Currently, a lot of drinking water treatment is used to get healthy and safety of drinking water. The water has certain standard requirements such as physical, chemical, bacteriological and radiological requirements set by the Indonesian Minister of Health No. 492/Menkes/Per/IV/2018. The raw material of drinking water from river also have natural estrogens [1,2]. The drinking water treatment process can be taken from the nearest water source, which is well water. Well water

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has the potential to be processed and made into drinking water in accordance with the provisions. Well water is also used as raw water for refill drinking water depots. Depot drinking water treatment that uses the ultraviolet (UV) system and the use of filters in filter tubes, these tubes consist of sand filter media and activated carbon. In line with the development of water treatment technology, some refill drinking water depots use a reverse osmosis system to process water. However, the processing of UV light has many disadvantages such as the addition of chlorine or ozone after the UV process, it is relatively difficult to determine the UV dose, the formation of biofilms on the surface of the lamp and there is still the potential for photoreactivation in pathogenic microbes that have been processed with UV. Reverse osmosis has disadvantages such as eliminating some minerals that are useful in water, requires high energy because this process operates at a pressure of 10–60 bar. Therefore, water treatment with UV and RO does not guarantee producing drinking water with good quality in accordance with drinking water quality requirements.

The latest research from Padang City Health Departmentprovides that 666 drinking water depots were found to be 18% ineligible and suitable for consumption [3]. The excessive use of ground water can cause a decrease in the surface of the land, so that it requires a quick and appropriate solution. One solution is to find alternative water sources that can substitute for ground water functions, the most potential alternative water source in Indonesia is rainwater. Indonesia received rainfall of 2,000-4,000 mm/year and varies greatly in various regions. In Padang, the average monthly rainfall is 405.6 mm/month with an average of 17 days of rain per month [4]. With high rainfall intensity, rainwater could be transformed into clean water, therewith drinking water as an alternative water source.

McMichael *et al*. [5]used photo electrochemical reactor (PEC) with a compound parabolic collector (CPC) to test the electrochemically assisted photocatalytic (EAP) disinfection of rainwater under real sun condition. The targeted environmental strains of *Escherichia coli* and *Pseudomonas aeruginosa* showed the reduction of 5.5-log10 and 5.8-log10 for *E. coli* and *P. aeruginosa* with relatively low UV irradiance. Du *et al*.[6]harvested rainwater and filtered through gravity-driven membrane (GDM) with the permeate flux of 4.0 $L/(m^2\ h)$ and showed the decreased of bacterial abundance within the permeate $((8.45 \pm 0.11)x10^2$ cells/mL) and also could produce a permeate that was almost free of particles [6]. Filtration technique using a metal membrane was designed and developed for efficient and safe use of rainwater. The study showed the high treatment efficiency of microorganism and particulates with the combination of ozone bubbling as aeration which considered to reduce membrane fouling and inactivate microorganisms [7]. Biosand filters have been demonstrated to inactivate harmful microorganisms as well as UV irradiation that has shown over 99.9% inactivation efficiency for *Cryptosporidium parvum* oocysts and *Giardia lamlia* cysts at low UV dose [8].

Numerous alternative disinfection has been suggested to purify rainwater from microorganisms. Radio frequency plasma system is an advance treatment used to produce drinking water with a small possibility of contamination. Plasma can generate oxidizing species radical($•OH^-$, •O, $•H^+$)and molecules (O_3 and H_2O_2) [9]. Theseoxidizing species have a high oxidation potential to disintegrate bacterial cells and decompose organic compounds in water [10]. Also, plasma can produce ultraviolet light and shock waves which can also decompose organic compounds [8].

Previous studies have been conducted with the investigation of the removal of pathogenic microorganisms using plasma system. However, the removal of microorganisms in water still below 100% [11, 12, 15]. Therefore, this study is objected to investigate the application of radio frequency plasma coupled with filtration process to produce drinking water from rainwater based on the evaluation of microorganisms' removal efficiency using different material of cartridge filter.

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2. Materials and methods

2.1 Rainwater sample

The rainwater was collected from the roof catchment in two different sampling locations located in Padang, West Sumatra, Indonesia. A rainwater was collected from Sinar Melayu Residence located in Jalan Gajah Mada Dalam, Padang. B rainwater was collected from Badan Pengawas Keuangan dan Pembangungan (BPKP) Residence 2A Nanggalo located in Jalan Shinta Kenanga, Padang, Indonesia. The distance between two site is 2.5 Km.

2.2 Cartridge filter used in the experiment

The filters used in this experiment are shown in Table 1.

Table 1. Cartridge Filter Material Type

Type of Filter	Material and Excellence
Filter I	• Made from Mix polypropylene • To filter turbidity and large, small particles in water • Pore size 1 µm
Filter II	• Made from Pure polypropylene • To filter turbidity and large, small particles in water • Pore size 1 µm

2.3 Radio frequency plasma-filtration system

The collected rainwaters were transferred to the raw water tank and pumped with a flow rate of 100, 150 and 200 mL/min through cartridge filter and flowed through plasma reactor coupled with copper wire under the frequency of 1.5MHz and electric current of 3A. Two different cartridge filters used in this study were 1 µm pure polypropylene and mix polypropylene filter (Table 1). The illustration of the process is shown in Figure 1. The treated rainwaters defined as drinking water were collected in the drinking water tank and analysed for total coliform, fecal coliform and *Salmonella*.

The number of microorganisms was measured with the plate count method [13,14]. The method used is the same as that describe in Desmiarti et al [15]. To analyse the number of pathogen bacteria, 1 mL treated water was poured onto a petri dish with a diameter of 5 cm, containing 4 mL of melted nutrient agar and the kept at 37 in an incubator for 24 h. The total number of bacteria was counted by enumerating purple, pink and white colonies formed as a fecal coliforms, total coliforms and *Salmonella*, respectively, in a colony-forming unit (CFU/mL.)

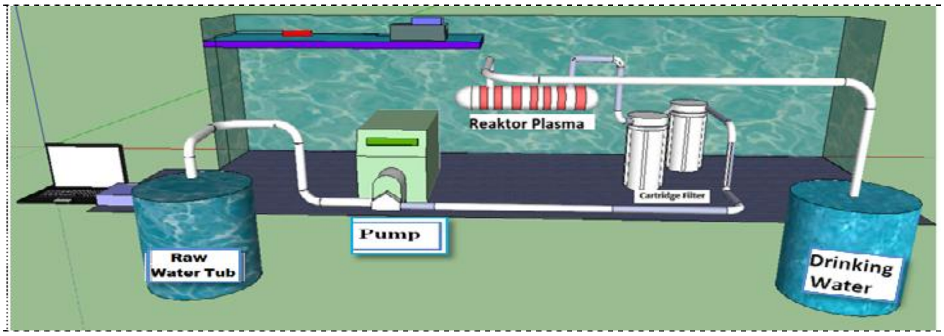

Figure 1. Experimental set-up of radio frequency plasma-filtration system

3. Results and discussion

3.1. Effectof flow rate on the removal of Salmonella *through a pure polypropylene filter*

A pure polypropylene filter could remove total coliform and fecal coliform in the rainwater, while *Salmonella* remained in the rainwater after filtration (Table 1). Figure 2 showed that the different flow rate caused a slight significant effect on removal of *Salmonella* in the first 10 min after plasma treatment. However, the removal efficiency of 100% was achieved after 40 min of treatment at all flow rate. The flow rate of 100 mL/min showed the highest removal rate in the first 10 min. This result is consistent with the previous study [14] that the removal of microorganisms will increase with the decrease of the flow rate during radio frequency plasma treatment system.

The efficiency on the removal of microorganisms also could be seen in the value of electric current and voltage which is determining the ionization process that occurs in water, the greater electric currentis applied, the ionization energy will release electrons is even greater. The voltage will also affect the amount of electric field that occurs in the reactor coil, as well as the electric current that affects the magnitude of the magnetic field[16].

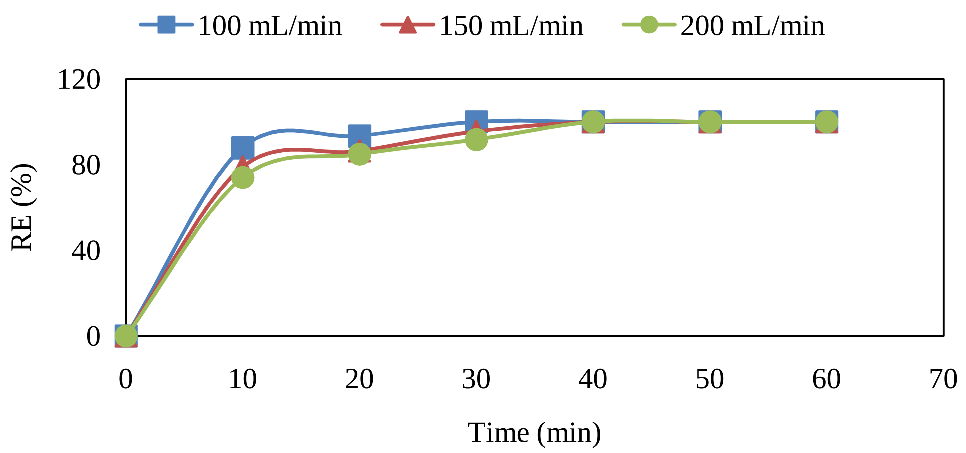

Figure 2. Effect of flow rate on the removal of *Salmonella* in rainwater after 60 minutes plasma treatment (RE: removal efficiency)

The combination of magnetic and electric fields is a factor that influences the electron ionization which serves to trigger the formation of plasma (oxidizing species) which kills microorganisms in water[17]. In this study, the picoscope was used with an electric current of 16.1 A and the voltage of 100 V. The high removal rate in after 10 min treatment at a flow rate of 100 mL/min could be supported finding by the influence of preferable electric field that formed during plasma treatment. The advantage of this combination of cartridge filter and radio frequency plasma compared to the DBD system is that the sample does not come in direct contact with the plasma and its application is simple. When comparedwith the electrolysis process which conducts in long treatment time, radio frequency plasma system requiresshort treatment time (60 minutes).

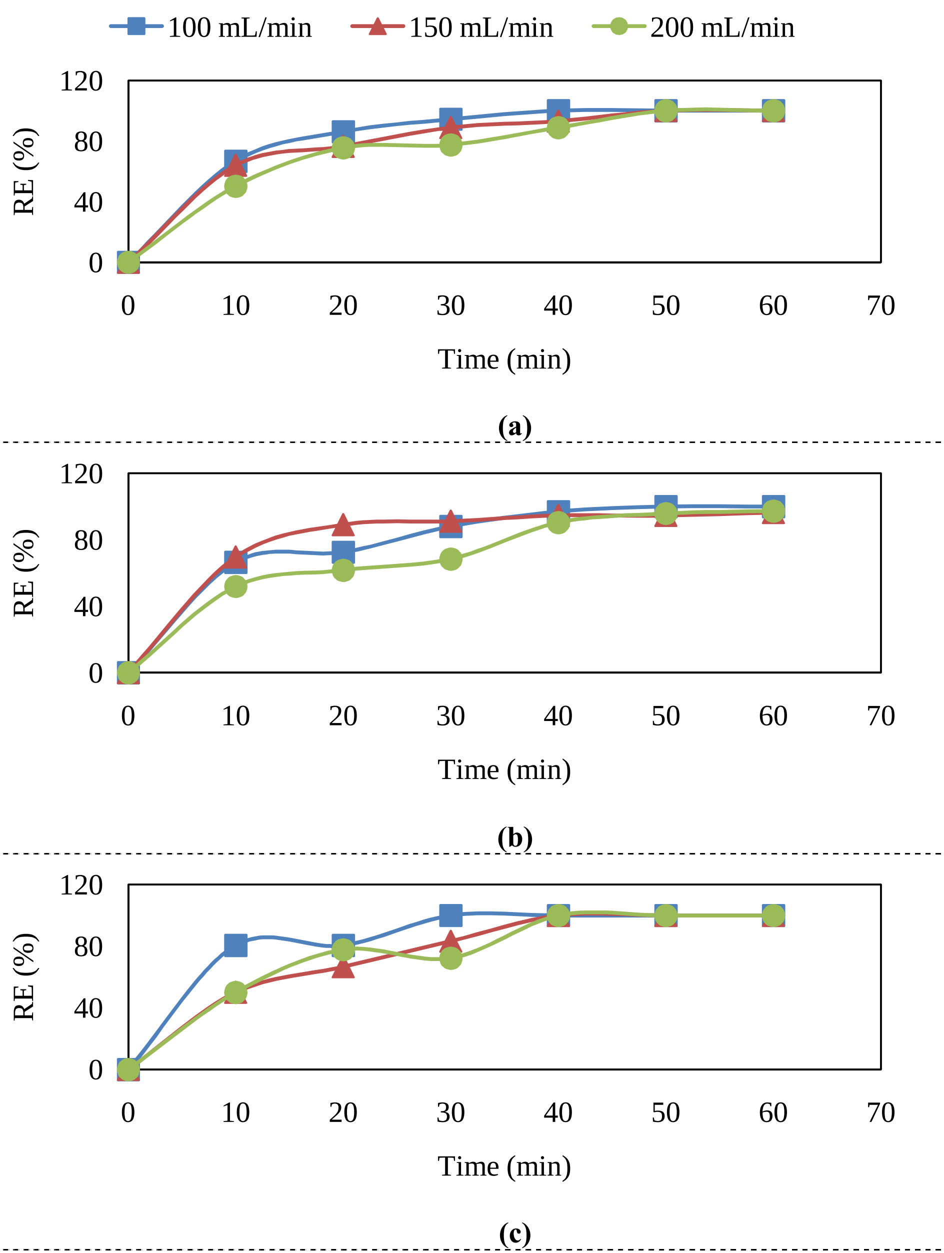

Figure 3. Effect of flow rate on the removal of (a) fecal coliform, (b) total coliform and (c) *Salmonella* after 60 minutes plasma treatment (RE: removal efficiency)

3.2. Effectof flow rate on the removal of fecal coliforms, total coliforms and Salmonella *through a mix polypropylene filter*

Figure 3 showed the comparison of the removal efficiency on different microorganism's consortium. Fecal coliform, total coliform and *Salmonella* has successfully 100% removed after 60 min with all different flow rate. This suggested that prolonged contact time could promote bacterial cells disintegration and organic compound decomposition by ultraviolet rays and shock waves produced during plasma treatment system in water [9, 12]. Additionally, an electric current of 16.1 A and voltage of 100 V applied in plasma system could also promote the rapid death rate (data not shown) of microorganisms accompanied with the formation of electric filed that formed active species during treatment which can disintegrate bacteria cells in the water [9].

The removal efficiency of 66.7 and 80.6% was achieved in the first 10 min at a flow rate of 100 mL/min for fecal coliform and *Salmonella*, respectively. This finding indicated that fecal coliform and *Salmonella* were susceptible to the electric wave produced during plasma treatment with low water flowrate.However, the removal efficiency offecal coliforms did not constantly achieve and there was a decrease in efficiency at some time during plasma contact in water. The inconstant removal of microorganisms was probably due to ununiform pores of mix polypropylene filter that caused microorganisms drifted during the filtration process.

3.3. Performance of combination treatment with radio frequency plasma and different filter type

Table 2 showed the combination treatment of radio frequency plasma system with different cartridge filter in the removal of microorganisms. Total coliform and fecal coliform were no longer present in the water because this pure polypropylene consists of fibrous material and uniform filter pores, making it more efficient for the water filtration system. This type of filter can filter total coliform and fecal coliform that are retained in the pores of the filter.Whereas*Salmonella* removal efficiency was 100% achieved in the different rainwater source at all different flow rates. Meanwhile, the combination treatment of radio frequency plasma system with mix polypropylene filter could achieve the removal efficiency of 96, 100 and 100% for total coliform, fecal coliform and *Salmonella*, respectively, at a flow rate of 100 mL/min in A rainwater. The removal efficiency of 100% was achieved for all microorganism at a flow rate of 100 mL/min in B rainwater. This finding indicated that microorganisms could be more susceptible against plasma and there was more contact with plasma to disintegrate bacteria cells with a low flow rate.

Table2. Removal of efficiency of microorganisms after 40 minutes of plasma treatment

Filter	**Rainwater**	**Flowrate (mL/min)**	**Removal efficiency (%)**		
			Total coliform	**Fecal coliform**	***Salmonella***
Pure Polypropylene	A	100	-	-	100
		150	-	-	100
		200	-	-	100
	B	100	-	-	100
		150	-	-	100
		200	-	-	100
Mix Polypropylene	A	100	96	100	100
		150	70	100	87.5
		200	70	89	83
	B	100	100	100	100
		150	94.6	93	100

(a)

	200	90	88.9	100

4. Conclusion

A combination treatment using radio frequency plasma and filtration process in different flow rate was investigated to remove fecal coliform, total coliform and *Salmonella* in rainwater. Different cartridge filters provided a significant effect on the presence of microorganisms, where fecal coliform and total coliform were undetected in the filtrate after filtration through pure polypropylene filter. The rapid removal efficiency was achieved using mix polypropylene filter with a flow rate of 100 mL/min in the first 10 min of treatment, indicating more microorganisms were contacted with oxidizing species at a low flow rate. A 100% removal efficiency for *Salmonella* was achieved in the 40 minutes of treatment, indicated that *Salmonella* was more susceptible against plasma compared to fecal coliform and total coliform. To assess a drinking water quality standard, further investigation is required, concerning the evaluation of organic and inorganic matter present in the rainwater.

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