Decreasing Iron (Fe) Contaminant from Ground Water for Water Treatment Processed by Dielectric Barrier Discharge Ozone Generator

by Abdul Syakur

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Abstract. At the end of the decade, we have been entered to the bad condition for water quality. As well as we know that water is a primary demand for everyone. Ozone is a very reactive oxidant, and it can oxidize any parameters in water quality and then that parameters can be reduced. The principal of electrical discharge ozone generator can produce ozone when the compilation of electricity flow through the electrode, after that the discharge electrons will bound with free air which containing O_2 so that O_3 (ozone is formed). In the research, electrical discharge for ozone generator was made with high voltage variation are 12 kV, 13 kV, 14 kV. Next, ozone concentration that produced by this generator is contacted to the groundwater sample in Semarang which containing 5,85 mg/litre iron and not yet required by World Health Organization *International Standard for drinking water* that is 0,3 mg/litre. The result shows, the highest production ozone concentration by this generator is 33,41 ppm and can decrease iron contaminant up to 23% from 5,85 mg/litre to 4,53 mg/litre. The lowest production ozone concentration is 2,85 ppm, and can decrease iron contaminant up to 12% from 5,85 mg/litre to 5,15 mg/litre.

1. Introduction

Iron is one of metal that usually contained in groundwater. The groundwater with low oxygen usually contains 10 – 100 mg/litre of iron. When the groundwater containing iron more than 1,0 mg/litre, it will considered aquatic organism life. World Health Organization *International Standard for drinking water* regulating the maximum iron level for drinking water is 0,3 mg/litre. Fe is an essential metal when, in a certain amount, is needed by the organism, but it will be toxic in excessive amounts. The high level of iron will have an impact for human health which is poisoning/vomiting, intestinal damage, premature ageing to sudden death, arthritis, congenital disability, bleeding gums, cancer, kidney cirrhosis, constipation, diabetes, diarrhoea, fatigue, hepatitis, hypertension, and insomnia [6]. [11] said that ozone formation and decomposition reaction could be described below:

$$O_2 + e \rightarrow 2O + e \quad (1)$$
$$O + O_2 + M \rightarrow O_3 + (M) \quad (2)$$
$$O_3 + O \rightarrow 2\,O_2 \quad (3)$$
$$O_3 + e \rightarrow O + O_2 + e \quad (4)$$

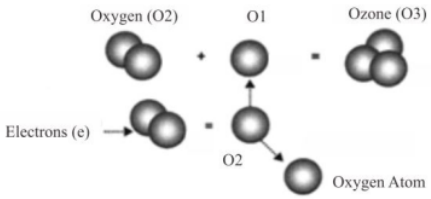

Figure 1. Ozone gas formation by collation between molecular and electrons processed [13]

According to [9], the principal of electrical discharge is passing though dry air or oxygen to space between 2 electrodes that are electrified by alternating high voltage electricity which is around 8.000 – 20.000 volts. Intermittent discharge takes places between two electrodes, and it will be caused the electrons collating with oxygen molecular and ozone (O_3) is formed.

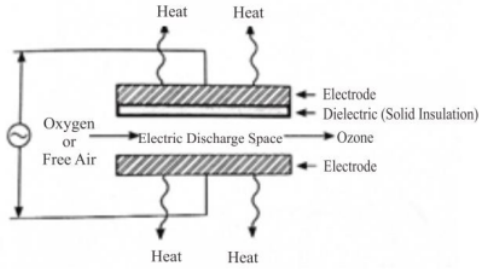

Figure 2. The principal of ozone generator by electrical discharge
Source: JWWA, 1978

Ozone Corona Discharge Plasma reactor with cylinder electrode configuration with DBD consists of 3 part which are positive electrode (shaped wire), negative electrode cylinder tube, and dielectric material as a barrier release between the positive electrode to the negative electrode [12] As an example, the ozone decomposition processed according to [5] is the following:

$$O_3 + H_2O \rightarrow HO_3^+ + OH^- \quad (5)$$
$$HO_3^+ + OH^- \rightarrow 2HO_2 \quad (6)$$
$$O_3 + HO_2 \rightarrow HO^* + 2O_2 \quad (7)$$
$$HO^* + HO_2 \rightarrow H_2O + O_2 \quad (8)$$

In this series of elementary reactions, ozone reacts with water to form, among other compounds, HO • (hydroxyl radical) and HO_2 (superoxide), which are very reactive and sometimes used for the destruction of organic compounds [1]. [2] says that water which containing iron is reacted with ozone gases can cause oxidation reaction so that in water dissolve iron is forming soluble iron. The estimation Fe^{2+} in Fe^{3+} oxidation reaction mechanism with ozone gasses according to Nowell and Hoigné theory is the following:

$$Fe2^+ + O_3 \rightarrow (FeO)^{2+} + O_2 \quad (9)$$
$$(FeO)^{2+} + Fe^{2+} + 2H^+ \rightarrow 2Fe^{3+} + H_2 \quad (10)$$
$$(\text{Equilibrium: } 2Fe^{2+} + O_3 + 2Fe^{3+} + O_2 + H_2O) \quad (11)$$

From the explanation above, we know that the goal of this research is to know the effectiveness groundwater treatment which contains iron into drinking water by oxidation process with ozone gasses which is included to Advanced Oxidation Process (AOPs) with electrical barrier discharge generator.

2. Methodology

Groundwater sample takes from Bukit Kencana Jaya Residence, Semarang City. Sample contacted by ozone that has been made by an ozone generator, the input is AC voltage as an independent variable is three variations which are 12 kV, 13 kV, 14 kV, and dry air which contain O_2 is pumped by aerator with a flowrate 0,5 litre/minutes. Based on [4] water sample with ozone contact time is 15 minutes and according to the previous research by Phramawati (2010) says that the highest decreasing Fe contaminant when the contact time for 15 minutes. Next, it is allowed to stand for 30 minutes to decompose ozone in water. After the sample was passed through the ozonation process, the iron level is tested at laboratory scale. DBD Ozone generator uses inner electrode (aluminium screw with diameter 8 mm) and outer electrode (circular coil made by copper wire with diameter 33 mm, full 0,5 mm and 42 turns with a length of 1386 mm. The barrier material is cylindrical glass with outer diameter 33 mm, wide 1 mm and a range of 23,5 mm.

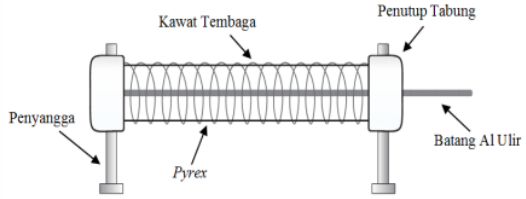

Figure 3. Dielectric Barrier Discharge Ozone Generator

3. Result

The result consists of 3 part, which is ozone concentration production, the effectivity of iron level decreased and the relationship of the removed iron and ozone production.

3.1. Ozone concentration production

This chart describes the result of ozone concentration production with high voltage variation.

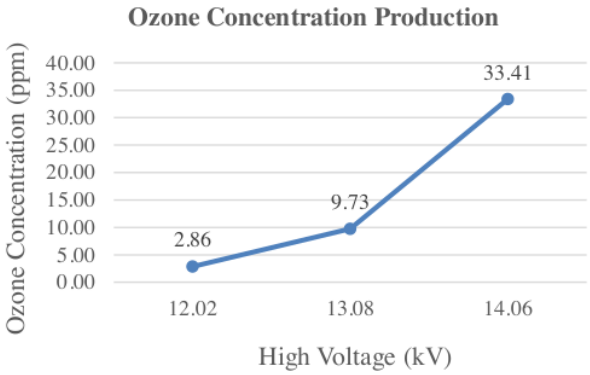

Figure 4. Ozone concentration production

According to the graphic, we know that the higher voltage was inputted into the generator; the production of ozone concentration is higher. Otherwise, the smaller voltage inputted into the generator, the output of ozone concentrations is lower. It caused by the electrodes that made of aluminium release the electrical charges when high-voltage electricity, so that the ionization process occurs. The higher

the input voltage, the more electrical charge is released from the aluminium metal, so that the condition of air input is fixed, it will cause this electrical charge to react with dry air. The more electrical charge that reacts with air containing O_2, the production of ozone concentration is higher.

3.2. Effectivity of iron level decreased

This chart describes the analysis of removal efficiency of iron level (before and after ozonation process).

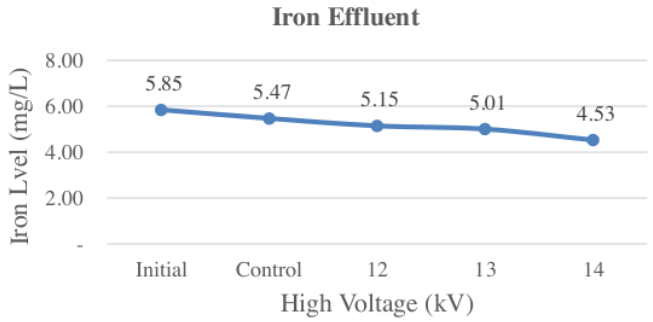

Figure 5. Iron effluent (before and after ozonation)

The chart showed that the greater voltage used for the ozonation process. The effluent of iron is smaller, and otherwise, the smaller voltage used for the ozonation process, the effluent of iron is greater. In this research, when the ozone generator is given the highest input a voltage of 14 kV, the iron decrease from 5.85 mg /litre to 4.53 mg /litre. However, it doesn't require the World Health Organization *International Standard for drinking water* that is 0,3 mg/liter. Because the function ozonation process converts Fe^{2+} ion to be Fe^{3+} ion by oxidizing Fe^{2+} ion, so that it changes physical properties from soluble to be solid, not to remove the ion. According to [8] oxidation reaction equation is the following:

$$2\ Fe^{2+} + O_3(aq) + 5\ H_2O \rightarrow 2\ Fe(OH)_3(s) + O_2(aq) + 4\ H^+ \quad (10)$$

Iron can decrease after this ozonation processed because the sample is taken at the bottom of Erlenmeyer because the solids that are formed are still in a cut in half position and even float. So that the solid iron hasn't all dropped to the bottom of Erlenmeyer and doesn't put into the bottle sample.

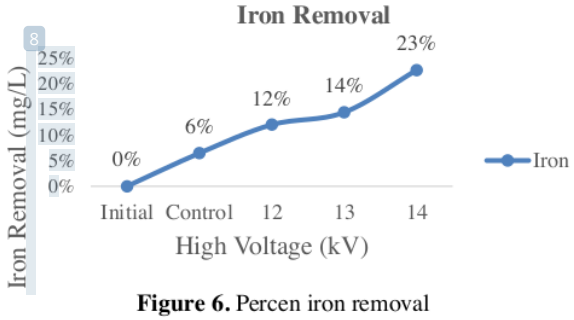

Figure 6. Percen iron removal

From the figure 6 we know that the higher voltage used. When % removal of iron in the sample water is more significant, and otherwise the smaller energy used, then % removal of iron in the sample water is lower. It happens because oxidation of ozone and metal that has been contacted into the sample because ozone is one of the methods of Advanced Oxidation Process (AOPs). Ozone is a

reactive gas so that the oxidation process using this gas can be claimed more quickly, but based on the results the chart, iron removal is quite low which is around 23% even though the ozone concentration formed is quite large.

3.3. The relationship between removed iron and ozone production

This chart shows the relationship removed iron and ozone production.

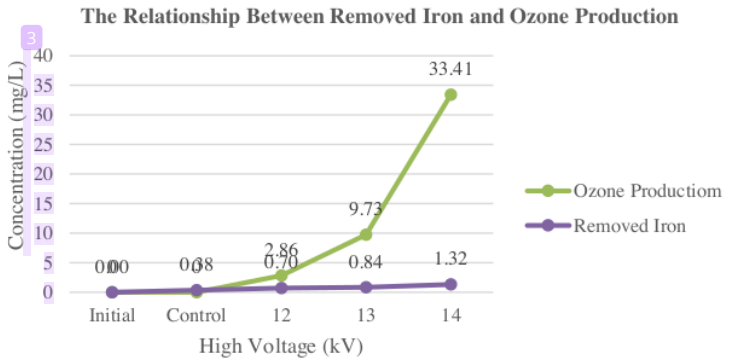

Figure 7. The Relationship Between Removed Iron and Ozone Concentration Production

According to the chart, it can be concluded that the lower the concentration of ozone that is contacted the decreasing of iron content in the water sample is lower. The iron is remained even though the concentration of ozone produced is very high. It possible caused by the pH is small. However, the alkalinity properties of sample is low and then the OH radical reaction process which functions to decompose ozone is getting slower, however the formation of Fe^{3+} to be $Fe(OH)_3$ is also delayed due to low pH and the presence of organic compound showing high alkalinity level of water [10].

Ozone decomposition in the ozonation process for iron removal is affected by rising temperatures which will reduce ozone solubility in water. Next, the pH contains OH^- hydroxide ions which accelerate the decomposition process, and alkalinity is inhibitor which slows the OH radical reaction while manganese and organic substances as initiators that accelerate ozone decomposition [7]. The result of Hoigné research shown that the response of ozone with Fe^{2+} in neutral pH solutions is faster (less than 2 minutes), because the oxidation between ozone and iron influenced by the pH of the solution which is the higher the pH causes the removal of iron is more top [3].

4. Conclusion

Based on this research, it can be concluded that the highest efficiency of iron removal by ozonation process with Dielectric Barrier Discharge Ozone Generator (material: screw aluminium as an inner electrode, copper wire as an outer electrode and glass as a barrier). It showed that maximum efficiency occurs at 14 kV voltage variations and the highest % iron removal is 23% from 5,85 mg/litre to 4,53 mg/litre and not require the drinking water quality requirements by World Health Organization *International Standard*. However, the groundwater is not possible to drink right away after ozonation treatment.

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