The Comparison of Ozone Residual Concentration in Groundwater and Springwater with Conventional Ozonation and
AOP (Advanced Oxidation Proces) Ozone-UV

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Abstract

Ozone is the strongest disinfectant compared to other disinfectants such as chlorine based disinfectant. In water, ozone will decompose into OH radicals, which are the most powerful oxidizing agent. Ozonation can be applied with both Conventional and Ozone-UV Advanced Oxidation Process (AOP) methods. Ozone-UV accelerates ozone decomposition into OH-radicals. This research aims at showing the influence of conventional ozonation and Ozone-UV on the concentration of residual ozone (C) at any contact time interval (T), as well as determining the influence of water quality to C and T. Bunga Bakung's groundwater (GW) and Mulyawangi's springwater (SW) were used as model water in semi-batch process at contact time intervals of 2, 4, 6, 8, 10, and 12 Minutes. For C measurement, Indigo Colorimetric method was used. It was found that C value in conventional ozonation was higher than Ozone-UV, both for GW and SW. The GW samples have higher C values, both in the Conventional ozonation and Ozone-UV. This condition is due to the high value of alkalinity in GW, which acted as an inhibitor in ozone decomposition.

Keywords : AOP Ozone-UV, desinfection, conventional ozonation, ozone residual concentration

1. INTRODUCTION

Nowadays in Indonesia, there has been a widespread application of ozone as a disinfectant. The reason for the use of ozone is due to far more superior oxidation ability of ozone to that other disinfectants. Ozone reacts directly with dissolved solutes, while the other parts decompose into hydroxyl radical as the strongest oxidant in water (Hoigne, 1983). Ozone is a very selective oxidant, but OH radicals quickly react with many dissolved compounds and water matrix (Von Gunten, 2003).

There are two types of ozonation processes, namely conventional ozonation process and advanced oxidation process (AOP). Both processes are widely applied for disinfection process in Indonesia. In conventional ozonation, decomposition of ozone into hydroxyl radicals is not accelerated. On the other hand in AOP process, decomposition of ozone is accelerated (Acero, 2001).

The ozone–UV combination can be applied on AOP. This combination process promotes the formation of highly reactive hydroxyl radicals. The Ozone-UV combination can lead to the increase of ozone transformation into hydroxyl radical. The reaction of ozone in the water is gas liquid heterogeneous parallel-series, in which ozone is transferred from the gas phase to the liquid phase. At the same time, while diffusing, it simultaneously reacts with other substances (pollutants) (Beltrand, 1995). Stability of ozone in water is influenced by water quality parameter such as temperature; pH; the type and concentration of natural organic matter (NOM) and alkalinity (Hoigne, 1994).

In this study, we investigated the influence of conventional ozonation and ozone-UV combination process to residual concentration of ozone from groundwater and spring water samples. This paper also discusses stability of ozone in both samples, to find out the influence of several water quality parameters on both processes to the concentration of residual ozone.

II. MATERIALS AND METHODS
2.1 Samples

Conventional ozonation was compared with the Ozon-UV prosess to evaluate its effect to the concentration of residual ozone in water. To characterize both oxidative systems, two water samples were taken. Those samples were groundwater (GW) and spring water (SW).

Samples were taken from Mulyawangi springs Ujung Berung and Bunga Bakung Groundwater. Both samples were taken from Bandung City - West Java, Indonesia. Concentration of residual ozone measurement were done at 2, 4, 6, 8, 10, and 12 minutes of contact times.

2.2 Experimental set up

The experimental set-up is presented in Figure 1. For conventional ozonation process, the equipments used are air pump which was equipped with air flow meter, ozone generator, and contactor with capacity of 2 liters for ozone-water reaction. The excess ozone released from the contactor was decomposed by scrubbing it into KI solution. For Advanced Oxidation Process, the equipments were the same with conventional ozonation process, with an addition of UV – C lamp 15 Watt.
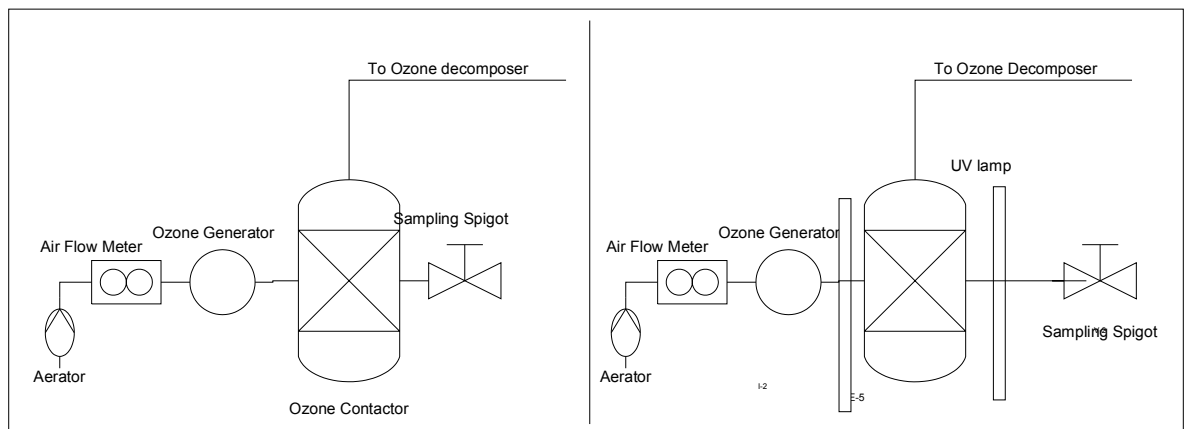
A Conventional Ozonation Process   B. AOP Ozone (Ozone and UV)

Figure 1. Experimental set up conventional ozonation process

Air pump (aerator) was applied to supply oxygen from air to ozone generator. The air flow was kept constant around 0,5 L/minutes. Ozone generator was equipped to convert air become ozone. Ozone, which was produced, then brought into a contactor where ozone in gas phase was transferred to liquid phase. Contactor was provided with filter disc with pore diameter of 16-40 microns, and a valve for water sampling.

2.3 Analytical Methods
A. Water quality measurement
Water quality parameters which being measured were: temperature, pH, alkalinity, organic matter with UV_{254}.
B. Ozone residual concentration measurement
Ozone residual concentration was determined by indigo Colorimetric method according to standard method 4500-O3-B.

III. RESULT AND DISCUSSION
3.1. Water Sample Characteristic

The characteristic parameters of the Groundwater (GW) and Spring water (SW) used in the experiment are shown in Table 1. Here, only important parameters were examined.

Table 1. Water Samples Characteristic

Parameter	GW Sample	SW Sample
Temperature (^{o}C)	24.3	23.5
pH	5.25	4.87
Alkalinity (mg/L $CaCO_3$)	167.45	39.4
Aromatic content (m^{-1})	10.1	1.4
Turbity (NTU)	12.2	4.15
Fe^{2+} (mg/L)	0.57	0.28

Table 1 shows that pH from both water samples were low. The temperatures were around the room temperature. The alkalinity and dissolved Fe of GW sample were higher than SW. Alkalinity as carbonate is known to inhibit ozone chain decomposition reaction (von Gunten, 2003).   The value of UV $_{254}$ was used to indicate the existence of aromatic NOM as LMW organic precursors during ozonation. Turbidity of GW sample was 12,2 NTU and SW sample was only 4.15 NTU.

3.2. Concentration residual of ozone versus contact time

Figure 2 shows the measurement of residual ozone at contact time interval in conventional and Ozone-UV process at GW and at SW samples.
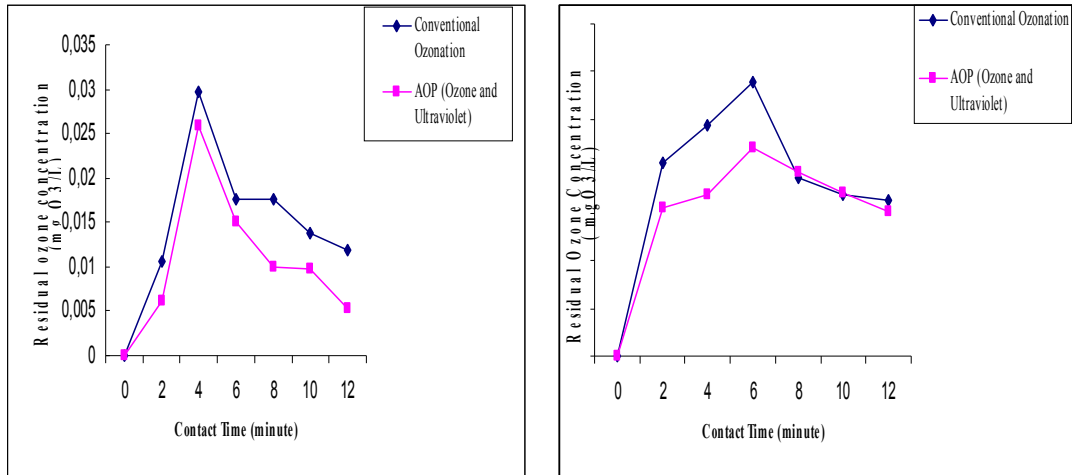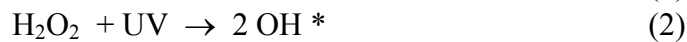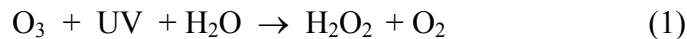
A.SW   **B. GW**

Figure 2. Ozone Residual Concentration VS Contact Time

It is seen from Figure 2 that concentration of residual ozone with conventional process was higher compared to ozone-UV. This phenomenon is happened as the result in ozone-UV processes, The ozone chain decomposition is initiated primarily by H_2O_2 (Fessenden, 1990):

$$O_3 \; + \; UV \; + H_2O \; \rightarrow \; H_2O_2 \; + O_2 \qquad\qquad (1)$$
$$H_2O_2 \; + UV \; \rightarrow \; 2\,OH \; * \qquad\qquad\qquad (2)$$

Reaction (1) and (2) are different compare to the conventional ozonation process in which OH^- initiate O_3 decomposition, due to following reactions (3) and (4) (von Gunten, 2003):

$$O_3 + OH^- \rightarrow HO_2^- + O_2 \qquad\qquad (3)$$
$$O_3 + HO_2^- \rightarrow OH^* + O_2^* + O_2 \qquad\qquad (4)$$
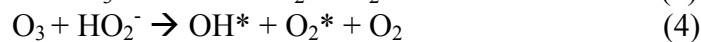
According to reaction (1) and (2), the initiation of ozone decomposition can be done by UV. This condition is likely to happen because in ozone-UV process, the UV accelerates ozone decomposition extensively by initiating the degradation of ozone, primary to the formation of hydroxyl radical (Acero et al, 2001).

Figure 2.B shows at 8 and 10 minutes of contact time the concentration of residual ozone in AOP process were lower than conventional process. The higher aromatic as UV 254 and Fe^{2+}, the more concentration of residual ozone reacted with those water matrix. This result shows that the characteristics of water have influenced the concentration of residual ozone (Hoigne,1994).

3.3. Comparison concentration of residual ozone at GW and SW

The concentration of residual ozone at GW and SW samples in both oxidative processes were measured to find out the influence of water characteristic to the stability of ozone in the water. Figure 3 shows the measurements of residual ozone with conventional ozone and Ozone-UV process which were taken at various contact times for GW and SW.
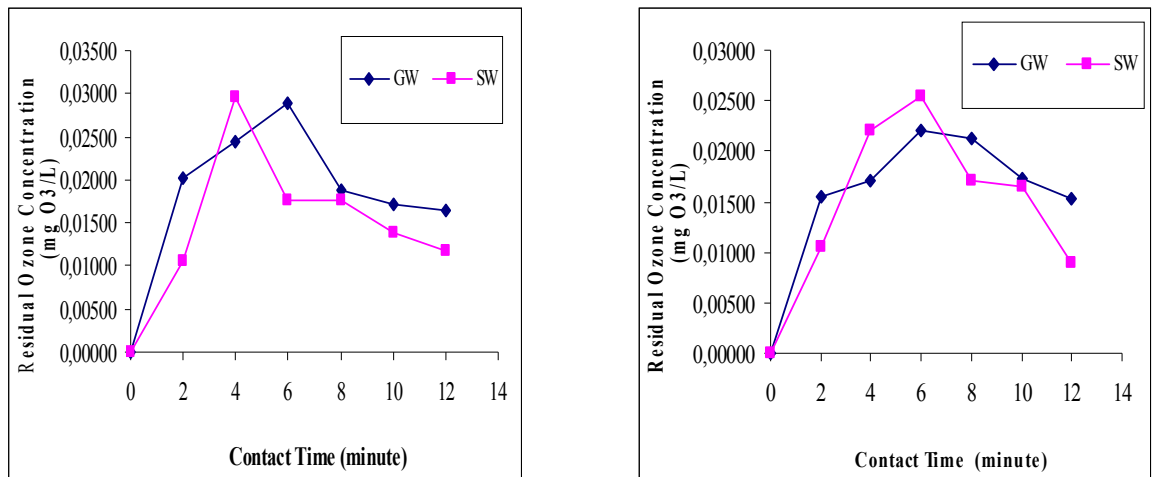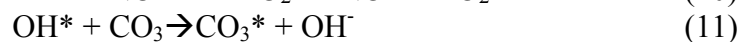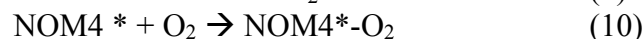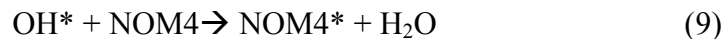

A. Conventional Ozone   B. AOP (Ozone-UV)

Figure 3. Concentration of residual ozone VS Contact Time

The figures show that the concentration of residual ozone on GW samples were commonly higher compare to SW samples. This condition may be affected by the water characteristics. In GW sample, alkalinity was higher compare to SW. As the result, decomposition of ozone is inhibited by carbonate and bicarbonate ions (Hoigne, 1994). Inhibitors are entities that do not release super oxide after the reaction with OH radicals. In natural waters, they consist of a fraction of the NOM and carbonate/bicarbonate, which involves the following reactions (von Gunten, 2003):

$$OH^* + NOM4 \rightarrow NOM4^* + H_2O \qquad (9)$$
$$NOM4^* + O_2 \rightarrow NOM4^*\text{-}O_2 \qquad (10)$$
$$OH^* + CO_3 \rightarrow CO_3^* + OH^- \qquad (11)$$
$$OH^* + HCO_3 \rightarrow CO_3^* + H_2O \qquad (12)$$

The bicarbonate radical is not important under typical drinking-water treatment conditions because it is quickly deprotonated (von Gunten, 2003).

Figure 3 also shows, only at 4 and 6 minutes of contact time the concentration of residual ozone at GW sample was lower than SW

sample. This condition happened because the turbidity level and aromatic content (as UV $_{254}$) values in GW were higher than SW.

Turbidity value can be indicated the water matrix. In GW, the water matrix was more complex than in SW, therefore the competition level between water matrix to react with ozone in GW would be higher than that in SW.

According to von Gunten (2003), organic matter can act both as inhibitor and promoter on ozone chain decomposition. Further research is needed to detect the type of organic content by GC-MS.

The effect of pH was not significantly influence the result, since the values were not significant.

IV. CONCLUSIONS

Ozone-UV process can accelerate decomposition of ozone compare to conventional ozonation process. Concentration of residual ozone at conventional ozonation and Ozone-UV strongly depends on the water characteristics. Alkalinity and organic content can affect stability of ozone in the water on conventional ozonation and Ozone-UV process.

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