# Disinfection Effect of Chlorine, Chlorine Dioxide and Ozone on Total Coliform in Water

Yoonjin Lee*[1], Kyoungdoo Oh[2], Byongho Jun[2], Sangho Nam[1]

[1]*Konkuk University, Seoul, 143-701 Korea*
[2]*Korea Military Academy, Seoul, 139-799 Korea*

**Abstract**

This research was to determine and compare the inactivation of total coliform as the indicator organism with chlorine, chlorine dioxide and ozone for drinking water treatment. The inactivation of total coliform was experimentally analyzed for the dose of disinfectant, contact time, pH, Temperature and DOC. The experiments for the characterization of inactivation were performed in a series of batch processes with the total coliform as a general indicator organism based on chlorine, chlorine dioxide and ozone as disinfectants.
The nearly 2.4, 3.0, 3.9 log inactivation of total coliform killed by injecting lmg/L at 5 minutes for chlorine, chlorine dioxide and ozone. For the inactivation of 99.9%, Disinfectants required were 1.70, 1.00 and 0.60 mg/L for chlorine, chlorine dioxide and ozone, respectively. The bactericidal effects of disinfectants were decreased as the pH increased in the range of pH 6-9. The influence of pH change on the killing effect of chlorine dioxide was not strong, but that on ozone and free chlorine was sensitive. The bactericidal effects of the disinfectants were increased as the temperature increase. The activation energies were 36,053, 29,822, 24,906 J/mol of chlorine, chlorine dioxide, ozone for coliforms. The inactivation effects were shown in the lowest order of chlorine, chlorine dioxide and ozone.

## Introduction

Disinfection has been used in the treatment of drinking water for many years to control waterborne diseases. Effective control of resistant pathogens in potable water requires not only the use of efficacious disinfectants but also optimal design criteria to cost-effectively protect public health while minimizing risk from exposure to disinfection by-products.

This research presents a more developed discussion that can be used to assess the applicability of various disinfectants to select an appropriate disinfection strategy for drinking water systems. The disinfection effects of chlorine, chlorine dioxide and ozone with regard to the dosage of disinfectant, contact time, pH, temperature and DOC was investigated experimentally.

## Materials and Method

In this study, samples were taken from a water treatment plant with a nominal capacity of 1,450,000 $m^3$/day, supplied with Han River water; the treatment process at the plant includes coagulation, sedimentation, filtration, and chlorination. Samples were collected at the point of the filter inlet. Water samples were collected aseptically with sterilized 1L Pyrex bottles, which had been specially treated by acid washing and baking at 300°C to remove carbon compounds. Appropriate volumes of the sample were filtered through the sand columns in our laboratory.

Free chlorine levels were determined by the DPD colorimetric method with a chemical chlorine kit (Hach chemical). The concentration of the stock chlorine dioxide solution was determined with a UV-visible spectrophotometer. Absorbance readings were taken at 360nm with a 1cm cuvette. A molar absorptivity of $1250M^{-1}cm^{-1}$ at this wave length was used to calculate the corresponding concentrations of chlorine dioxide. Ozone residual analyses were conducted following the standard colorimetric method. Indigo stock solution was prepared from potassium indigo trisulphonate-concentrated phosphoric acid and anhydrous monobasic sodium phosphate. Samples were analyzed at 600nm with UV spectrophotometer (UV-1601, Shimadzu). Total coliform was enumerated in accordance with a membrane filtration procedure in the US standard method 9222B.

## Results and Discussion

Various doses of disinfectants were added into a given volume of solution containing a given bacterium reacted at 20°C for 5min. The results are shown in Fig. 1. As can be seen, chlorine, chlorine dioxide and ozone possess fair killing effects on total coliform and the killing effects were strengthened gradually as the dose of disinfectants were increased. After 5min contact time, the inactivation was 2.42, 2.99 and 3.93 $\log_{10}$ reduction when ozone, chlorine dioxide and chlorine were 1mg/L, respectively. The killing effect of ozone was better than that of chlorine dioxide and chlorine. For example, if 99.9% of the killing effect was attained, the required amount of ozone was about 0.6mg/L, chlorine dioxide was about 1.0mg/L, but for the chlorine, 1.7mg/L was required.

Fig. 2 shows the impact of pH on the disinfection of total coliform and demonstrates increases in the killing effects with decreasing chlorination pH. The higher the pH is, the lower the ratio of HOCl and the weaker the activity is, and the poorer the disinfectant effects are. As can be seen from the tests, the influence of pH change on killing effect of chlorine dioxide was not strong. In the range of pH 6-9, coliforms may be killed effectively by chlorine dioxide. As the pH of solution is decreased, ozone becomes more stable. In the general case molecular ozone is the predominant oxidative agent. Wickramanayake et al. suggest that differences in membrane constituents can lead to variations in ozone permeability or pH sensitivity.

The inactivation effects of the disinfectants were increased as the temperatures were increased. If the temperature is raised by 10°C, log survival ratio of coliforms inactivation with chlorine can be increased by 0.2. The difference of inactivation rate for ozone between at high temperature and at low temperature should increase more than the other disinfectants.

The dependence of the inactivation rate constant on temperature was analyzed using the classical Arrhenius expression. A plot of rate constants according to the Arrehenius expression and the corresponding fitting line are presented in Fig. 3. The inactivation energy of chlorine, chlorine dioxide and ozone to inactivate coliforms under 10 to 30°C and pH 7.0, may be given about 36,053, 29,822 and 24,906 J/mol. The activation energies are higher. It is thus clear that coliforms are killed easier by ozone on the inactivation.

To examine the effect of DOC concentration on the inactivation of coliforms, chlorine, chlorine dioxide and ozone were injected at a 1mg/L disinfectant dose and DOC levels of 2.54 and 4.54mg/L. If the DOC is raised by 1mg/L, log survival ratio of coliforms inactivation with chlorine, chlorine dioxide and ozone can be decreased 0.16. 0.25 and 0.37.

DOC is a significant factor on inactivation kinetics. Acha et al. reported that chlorine dioxide primarily reacts with organic compounds as an electron-transfer oxidant with the formation of oxygenated products as diols, aldehydes, ketones and carboxylic acids. Increasing DOC concentration results in a further decrease of inactivation with ozonation because of the higher consumption of ozone and HO· at higher DOC concentrations. Ozonation of water containing DOC results in direct consumption of molecular ozone without the formation of byproducts, as bonds within the organic molecules are cleaved and reproportioning the electron charge from the ozone.

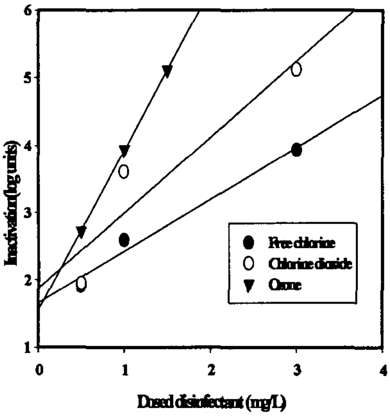


**Fig. 1**. Total coliform inactivation at different disinfectant dosage.

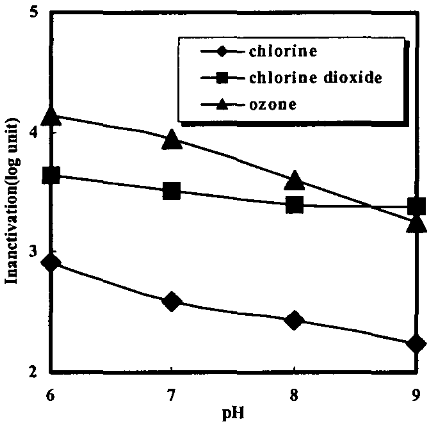


Fig. 2. Total coliform inactivation at different pH value

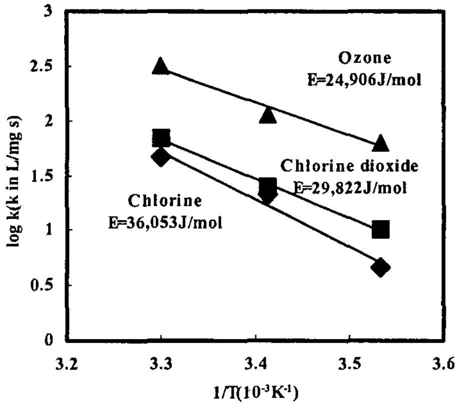


Fig. 3. Arrhenius plots for the inactivation rate constants.

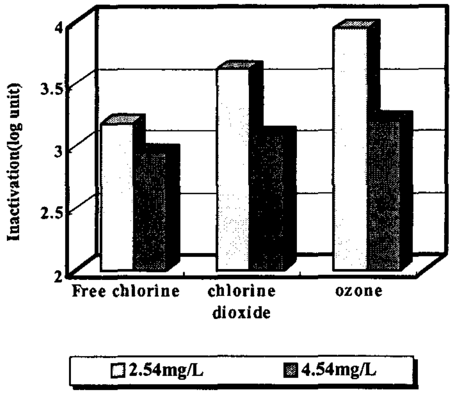


Fig. 4. Total coliform inactivation at different DOC.

## References


1. Acha, R. C., Serri, A., Choshen, E and Limoni, B. : Disinfection of drinking water rich in bromide with chlorine and chlorine dioxide while minimizing the formation of undesirable by-products. *Wat. Res.*, 17, 611-621, 1984.
2. American Public Health Association, American Water Works Association and Water Environment Federation. : Standard methods for the examination of water and wastewater, 19th ed. American Public Health Association, Washington, DC, USA, 1995.
3. Cho, J. H., Kim, J. Y and Yu, Y. C. : Disinfection of *E-coli* in water by use of ozone. *Journal of the Korean Society of Water and Wastewater.*, 2, 43-49, 1989.
4. Farooq, S., Chain, E. S and Engelbrecht, R. S. : Basic concepts in disinfection with ozone. *Journal of Water Pollution Control Federation.*, 49, 1818-1831, 1977.
5. Hunt, N. K. and Marinas, B. J. : Kinetics of *Escherichia coli* inactivation with ozone. Wat. Res. 31, 1355-1365, 1977.
6. Lee, Y. J., Lee, H. and Nam, S. H. : Factors on the formation of chlorite and/or chlorate in drinking water treatment using chlorine dioxide, *Journal of Korean Society of Environmental Engineers.*, 23, 153-161, 2001.
7. Miller, D. G. : A Survey of *Cryptosporidium Oocysts* in surface and groundwaters in the UK. *Journal of the Institution of Water and Environmental Management.*, 6, 697-703, 1992.