Metals Disinfection of *E. coli* in Synthetic Ground Water

J.N. Edokpayi*, R. Singh**, J.O. Odiyo* and J.A. Smith**
**Department of Hydrology and Water Resources, University of Venda, Private Bag X5050, Thohoyandou 0950, South Africa
**Department of Civil and Environmental Engineering, University of Virginia

ABSTRACT

Sustainable access to clean and safe drinking water remains a global challenge as large numbers of people still consume water that is not clean and safe. Diarrhea; a preventable waterborne disease remains the major cause of death among children under the age of 5 in most developing countries of the world. Several technologies have been invented to provide point-of-use water treatment. The cost of these technologies often limits their application. This study seeks to evaluate the use of several metals at concentrations below the World Health Organization recommended guideline values in drinking water as potential disinfectants for point-of-use water treatment. The bactericidal activity of Ag^{+}, Cu^{2+}, Co^{2+}, Ni^{2+} and Zn^{2+} against a non-pathogenic strain of *E. coli* in synthetic ground water was evaluated. Different concentration of silver varying from 20-80 µg/L were tested for disinfection efficiency. Samples were taken at 0, 2, 4, 6, 8, 18 and 24-hour time points. Similarly, copper concentrations were varied in the range of 200-800 µg/L. Samples were withdrawn at 0, 4,6,8,12,18 and 24 hours to count viable bacteria using the IDEXX technique. Results showed that 80 µg/L of Ag^{+} gives 4log-8.5log reduction of *E. co*li between 2 to 24 hours. While, 800 µg/L of Cu^{2+} showed 1log-7log reduction of *E. coli* in the range of 4 to 24 hours. A very high concentration (2800 µg/L) of Zn showed 1log-5.2log reduction of *E. coli* between 24-72 hours. Whereas, Co^{2+} and Ni^{2+} did not show any significant disinfection of *E. coli* even after 72 hours.

Keywords: Disinfection, *E. coli*, metals, synthetic groundwater.

1 INTRODUCTION

Clean and safe drinking water is desirable for a healthy society and economy. Unfortunately, the access to such water on a continuous basis is uncommon in many places of the world. Death recorded from waterborne diseases is alarming and this problem is exacerbated in developing countries of the world [1-4]. Microbes in water has been associated with fatal incidences of diarrhea, cholera, typhoid, hepatitis and a host of other health problems [5-6]. Diarrhea is a major disease responsible for the death of millions of children annually around the world [2, 5-6].

A host of metals and metalloids like Hg, As, Ag, Au, Cu, Zn and Pb have been used as antimicrobials in food and other agricultural products, as well as in medicine. A few of them like Ag and Cu have been applied as disinfectants in water treatment [5-7]. Silver and its compounds have been widely used to eliminate various classes of pathogenic organisms from drinking water. The major setback of Ag disinfection is the initial cost of silver owing to its wide range of application. Copper on the other hand provides a more affordable alternative for water treatment because it is about ten times cheaper than silver and has a high permissible limit in drinking water [8-9]. Sudha *et al* [7] reported that storing drinking water in a copper pot eliminates pathogenic bacteria from the water.

A comparative disinfection of *E. coli* by a host of metals in water of varying water chemistry is lacking. Therefore, this paper seeks to establish the disinfection of *E. coli* by a group of metals in synthetic ground water (SGW).

2 MATERIALS AND METHODS

Test solutions of silver (20 µg/L, 40 µg/L, 60 µg/L and 80 µg/L), copper (200 µg/L, 400 µg/L, 600 µg/L and 800 µg/L), cobalt (200 µg/L and 400 µg/L), nickel (200 µg/L and 400 µg/L) and zinc (1200 µg/L and 2800 µg/L) were prepared by diluting their respective reference standards (1000 mg/L) with deionized water. All the standards were purchased from Fisher Scientific. Synthetic groundwater was prepared as reported by EPA [10]. *E. coli* was grown and cultured and quantified as reported in literature [11]. The anionic and metallic constituents of both kinds of water were analyzed using an ion chromatograph connected to an autosampler (Dionex, ICS5000+)

3 RESULTS

Figures 1 and 2 shows bacteria inactivation as a function of time by various metal concenentrations, while Table 1 shows the water chemistry of the synthetic groundwater used in the study.

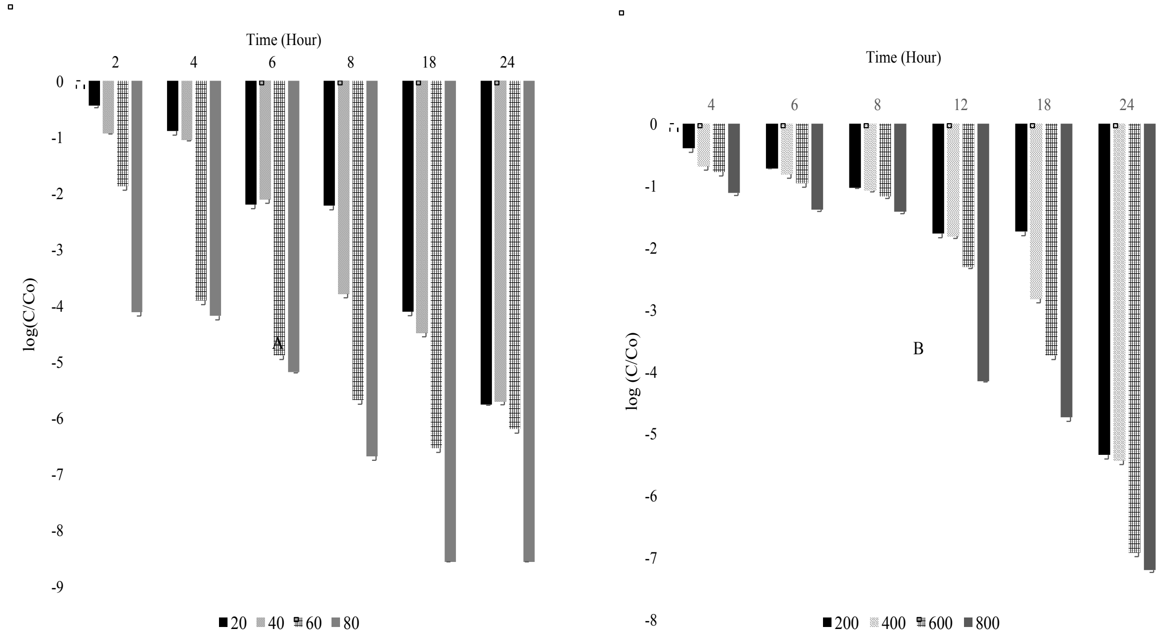
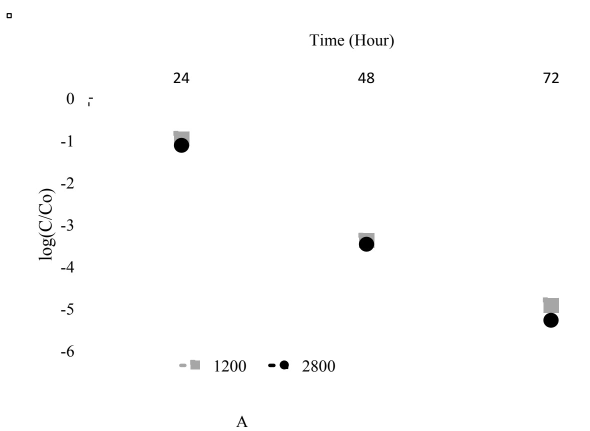
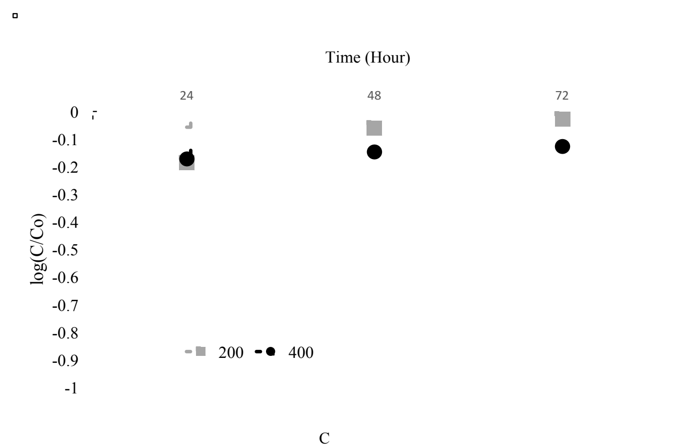


Figure 1: Effects of disinfectant concentration as a function of time on disinfection of *E. coli* in a synthetic ground water (SGW) in batch experiment. Error bar represent standard deviation for duplicate measurement, C represent concentration and Time t while Co represent the initial bacteria concentration at time 0. In A and B, disinfectant is Ag^{+} and Cu^{2+} respectively.





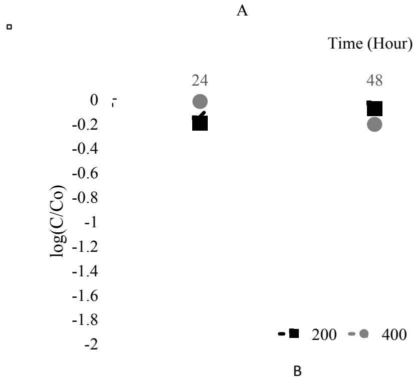


Figure 2: E.coli inactivation by Zn (A), Co (B) and Ni (C) as a function of time in SGW. Error bar represent standard deviation for duplicate measurement, C represent concentration and Time t while Co represent the initial bacteria concentration at time 0.

Table 1: Physico-chemical characteristics of synthetic groundwater (SGW)

Parameters	SGW
pH	8.16
Temp (^oC)	21.3
Conductivity (µS/m)	244
Dissolved oxygen (mg/L)	9.64
Potassium (mg/L)	2.65
Sodium (mg/L)	36.9
Calcium (mg/L)	21.9
Magnesium (mg/L)	14.0
Sulphate (mg/L)	82.0
Chloride (mg/L)	2.14

The SGW recipe prepared showed values which are consistent with natural groundwater.

In the SGW, a 4log reduction of the initial *E. coli* concentration was observed with 80 µg/L of Ag^+ within 2 hours of disinfection, while a 3.9log reduction was recorded for 60 µg/L within 4 hours of disinfection. 2-6.7log reduction of *E. coli* was achieved with 20-80 µg/L of Ag^+. 4-8.5log and 5.7-8.5log reduction were recorded for 18 and 24 hours' disinfection time. This implies that 99% inactivation of *E. coli* was acheieved with 20 µg/L within 6 hours of disinfection whereas 99.99% inactivation was attained within 2 hours with 80 µg/L of Ag^+.

A 90% inactivation of *E. coli* was only acheieved by 800 µg/L in 4 hours. 99% and 99.99% inactivation was only attained by 600 µg/L and 800 µg/L in 12 hours. Over 99.99% inactivation was acheieved by all the test concentration of Cu^{2+} within 24 hours

Preliminary inverstigation on the disinfection potential of Zn^{2+} was carried out within the concentration range of 200-1000 µg/L, insignificant disinfection was observed within the first 24 hours of disinfection. Similar results were obtained with the preliminary studies of Co and Ni ions within concentrations below drinking water permissible limit in 24 hours. However, 3–5log reduction of *E. coli* was determined after 48 hours and 72 hours, respectively. Insignificant difference in disinfection efficiency was observed when Zn concentration was increased from 1200 µg/L to 2800 µg/L. There was no significant disinfection recorded for nickel and cobalt ions, respectively up to 72 hours of disinfections.

4. DISCUSSION

This study has clearly shown that Ag^+, Cu^{2+} and Zn^{2+} exhibit varying potentials for the inactivation of *E. coli* in water. Silver ion was the best metal disinfectant studied and this account for its wide use in drinking water treatment devices [12,]. Copper, a micro-nutrient required for normal metabolic processes in humans also showed a significant inactivation of *E. coli* [13]. It can serve as a good alternative to Ag in drinking water treatment because it is cheaper and have a higher permissible limit of 1000 µg/L in drinking water. The microbial resistant of pathogens in water to silver ion also makes copper a promising alternative for drinking water treatment.

The synergistic effect of Cu and Ag ions have been explored in the treatment of legionella pneumophila in water systems in hospitals [14]. Copper metallic surfaces and copper pots used in storing drinking water have been reported to have significant inactivation of bacteria [5-6]. The use of Zn as a metal disinfectant is also promising owing to its use as a supplement for treating diarrhea mostly in developing countries of the world where the continuous use of clean and safe drinking water has not been met [15]. A significant inactivation of 99.99% of *E. coli* was attained after 24 hours of disinfection. The contact time of at least 48 hours needed for significant inactivation of E. coli is the major limitation to the use of Zn^{2+} for treating drinking water.

In conclusion, the higher concentration of metal disinfectants achieves better bacteria inactivation. Contact time also played a significant role in the disinfection efficiency of the metals. Silver ion disinfection of *E. coli* was achieved in a shorter time of disinfection when compared to Cu^{2+} and Zn^{2+}. In cases where disinfection time is not a limiting factor, Cu^{2+} and Zn^{2+} can be a better alternative. The use of copper and zinc as candidates of various point-of-use water treatment devices should be explored owing to their cost and higher permissible limits in drinking water than silver.

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