http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 8 (6): 910-913, 2005
ISSN 1028-8880

Investigation of Water Disinfection by Electrolysis

[1]Ali Reza Rahmani, [1]Ahmad Jonidi Jafari and [2]Amir Hossein Mahvi
[1]School of Public Health, Department of Environmental Health,
Hamadan University of Medical Sciences, P.O. Box 4171-65175, Iran
[2]Department of Environmental Health Engineering,
School of Public Health, Institute of Public Health Research, Center for Environmental Research,
Tehran University of Medical Sciences, P.O. Box 14155-6446, Iran

Abstract: The main purpose of this study was to conduct experimental investigation of water disinfection by using the electrolysis method. Inactivation and killing *Coliform* in polluted waters are investigated by different voltage, electrodes (Al, St and Cu) and 5 min electrolyze time. The experimental results showed that the removal efficiency depends on the voltage and electrode materials. From the experiments carried out at 10 V and at current intensity of 135 mA, it was found that 5 min period was sufficient for disinfecting water by Stainless steel electrodes.

Key words: Drinking water, disinfection, electrolysis, *Coliform*

INTRODUCTION

The practice of elimination of unhealthy microorganisms in water dates back to ancient times. The most common methods for water disinfection are using chemicals, ozonation, UV ray, membrane processes and etc.[1]. In the past, the primary emphasis of disinfection was prevention of water-born diseases by controlling some bacteria such as *Coliform*. A new finding made in 1970 resulted in significant reevaluation of this long established disinfection practice was about disinfection by products[1]. This disinfection by products, formed via the reaction between disinfectants and certain organic matters in water, may be harmful to human health[2]. Thus, the new methods for decreasing the side effects of disinfectants must be improved. The killing and inactivation of bacteria and yeast cells by electrochemical means have been well documented[2-5]. Several mechanisms have been proposed to account for the lethality of electrochemical exposure, including oxidative stress and cell death due to electrochemically generated oxidants, irreversible permeabilization of cell membranes by the applied electric field and electrochemical oxidation of vital cellular constituents during exposure to current or induced electric fields[2,5].

Chemical oxidants are generated when electric current is applied to aqueous suspensions of microbes with immersed electrodes[6]. Electrolysis at the electrodes in the presence of oxygen generates a variety of oxidants, including hydrogen peroxide, OH^- and ozone and at the presence of chloride ions, free chlorine and chlorine dioxide are in the solution[1,7,8]. Such oxidants are responsible for most, but not all, of the lethality of the applied direct current. Current research indicates that antimicrobial agents and electric current act synergistically to inactivate microbes[6]. A great deal of researches has focused upon the use of electric fields and currents to kill bacteria and yeast in industrial and medical applications[3,5,6,9-11].

The mechanism of the electrochemical process in aqueous systems is quite complex. Oxidation of the electrochemical process occurs, respectively at the anode and cathode of the electrodes according to Alley[12].

Cathode $$H_2O + e^- \rightarrow OH^- + \frac{1}{2}H_2 \quad (1)$$

Anode $$Cl^- \rightarrow \frac{1}{2}Cl_2 + e^- \quad (2)$$

Net $$H_2O + Cl^- \rightarrow OH^- + \frac{1}{2}H_2 + \frac{1}{2}Cl_2 \quad (3)$$

The main objective of this research was to conduct experimental investigation into water disinfection by using the electrochemical method. Removal or inactivation of microbial indicator in water was investigated by different current intensity, electrodes and distance between electrodes in constant electrolyze time.

Corresponding Author: Dr. Ali Reza Rahmani, Department of Environmental Health, School of Public Health, Hamadan University of Medical Sciences, P.O. Box 4171-65175, Hamadan, Iran

MATERIALS AND METHODS

Bacteria culture and culturable counts: The effect of electrical current on disinfection was tested on *E. coli*. Bacterial sample was taken from polluted water and grown in Lactose broth (Merck) on an orbital shaker at 35°C for 24 to 48 h until was gotten turbid. From this culture, sample was inoculated into EMB agar (Merck). Plates were incubated at 37°C for 24 h. Then, a colony of culture produced in EMB agar was added to 1000 mL water. Most Probable Number of *Coliform* in samples were measured as MPN/100 mL before and after electrolysis by using the Five Tube Fermentation Technique[12,13].

Experimental set-up and measurements: In these experiments, the electrochemical cell consisted of a sterile 500 mL beaker and two electrodes. Stainless steel, aluminum and copper plates (15.0 x 4.0 cm) were used as electrodes. The combinations of electrodes were selected as: (St-St), (Al-Al), (Cu-Cu), (St-Cu), (St-Al) and (Al-Cu), respectively. They were treated with the solution of HCl (15% wt.) for cleaning prior to use. The beaker was filled with 250 mL of sample water, (pH 7.5) and the electrodes plates were held suspended 2, 4 and 8 cm apart in the water, respectively. The experimental apparatus was set up in Hamadan University of Medical Sciences in 2004. Experiments were done similarly via the same electrolyzes time, electrodes distance and voltage intensity for all types of combinations of electrodes. To evaluate of the direct current effect on disinfection, the samples were exposed to different voltage (5, 8, 10, 15, 20 and 25 V) for 5 min, respectively. In this study current was changed from 50 to 400 mA according to voltage. Post-exposure counts were then performed. The experimental apparatus is given in Fig. 1.

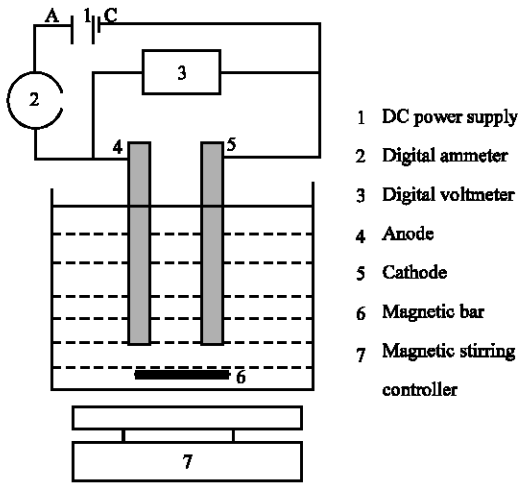

Fig. 1: Experimental apparatus

Power was supplied to the electrodes with a DC power supply. A magnetic stirrer was used for stirring. Cell current and voltage were measured using Ammeter and Voltmeter.

RESULTS AND DISCUSSION

The effects of direct current on water disinfection are shown in Table 1 to 6 for all combinations of electrodes. The results showed that disinfection was increased with increasing voltage. It was found that the lower distance between stainless steel electrodes had the highest disinfecting efficiency.

Disinfection rate by St electrodes appears to be higher than that by Fe and Cu electrodes singly. Matsunaga *et al.*[11] used carbon-cloth electrodes for disinfection of drinking water and they showed that water could be sterile when water contaminated by *E. coli* at a potential of 0.7 V Kumar *et al.*[3] reported that electrolyzed oxidizing water is highly effected in killing *E. coli* 0157:H, *Salmonella enteridis* and *Listeria monocytogenes* and it can able to complete inactivation by 10 min of exposure time. The voltage between the electrodes in that study was 10 V.

Table 1: Effect of current intensity on disinfection by St-St electrodes

	MPN/100 mL		
	Distance between electrodes (cm)		
Voltage	2	4	8
5	3.6	5.1	6.9
8	2.2	3.6	5.1
10	0.0	2.2	3.6
15	0.0	1.1	1.1
20	0.0	0.0	0.0
25	0.0	0.0	0.0

Table 2: Effect of current intensity on disinfection by Al-Al electrodes

	MPN/100 mL		
	Distance between electrodes (cm)		
Voltage	2	4	8
5	12	12	23.0
8	9.2	9.2	16.1
10	6.9	6.9	12.0
15	5.1	5.1	6.9
20	3.6	3.6	5.1
25	1.1	1.1	3.6

Table 3: Effect of current intensity on disinfection by Cu-Cu electrodes

	MPN/100 mL		
	Distance between electrodes (cm)		
Voltage	2	4	8
5	6.9	12	12.0
8	6.9	9.2	9.2
10	5.1	6.9	6.9
15	3.6	5.1	5.1
20	1.1	3.6	3.6
25	0.0	1.1	2.2

Table 4: Effect of current intensity on disinfection by Al-St electrodes

	MPN/100 mL		
	Distance between electrodes (cm)		
Voltage	2	4	8
5	5.1	6.9	9.2
8	3.6	5.1	5.1
10	2.2	3.6	3.6
15	0.0	2.2	2.2
20	0.0	0.0	1.1
25	0.0	0.0	0.0

Table 5: Effect of current intensity on disinfection by Cu-St electrodes

	MPN/100 mL		
	Distance between electrodes (cm)		
Voltage	2	4	8
5	5.1	6.9	9.2
8	3.6	5.1	6.9
10	2.2	3.6	5.1
15	0.0	2.2	3.6
20	0.0	1.1	2.2
25	0.0	0.0	0.0

Table 6: Effect of current intensity on disinfection by Al-Cu electrodes

	MPN/100 mL		
	Distance between electrodes (cm)		
Voltage	2	4	8
5	6.9	6.9	9.2
8	5.1	5.1	6.9
10	3.6	3.6	5.1
15	2.2	2.2	3.6
20	1.1	1.1	2.2
25	0.0	0.0	1.1

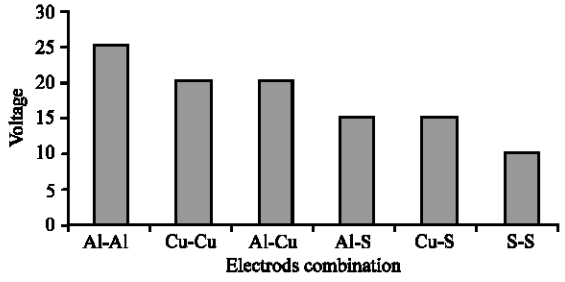

Fig. 2: Comparison of disinfection as a function of combination of electrodes (Potential: 5-25 V, contact time: 5 min and electrodes distance: 2 cm)

Disinfection as a function of combined electrodes and voltage in 2 cm distance between electrodes and 5 min contact time are compared in Fig. 2. When St electrodes are used, it was found that disinfection required lower current. When Al or Cu electrodes is used, need to increase voltage up to 20 and 25 V, respectively. When the combinations of St electrode with the others were used voltage decreased to 15 V. The effect of current intensity by both Al-St and Cu-St electrodes is found to be approximately the same.

It is thought that increasing electrolyze time or current intensity improves the efficiency of disinfection by faster producing hydrolyze products. During electrochemical treatment, when a potential is applied between electrodes, hydroxyl ions and Cl^- are generated at the cathode and anode, respectively. It is known that these products are responsible for disinfection. The possible combination of various hydrolysis products is endless and one or more of them may be responsible for the observed action of disinfection[2,6,8].

It was shown that the efficiency of water disinfection was depended significantly on the applied current intensity and electrodes material. These enhancing effects are attributed to the increase in the driving force of the electrode reaction and the increase in current voltage. This is because potential is the major driving force for the respective phenomena of interest in electrochemical reactors.

Majsunaga *et al.*[5] contaminated drinking water with *E. coli* K12 (100 cells/cm^3) was disinfected at a rate of 600 cells/cm^3/h with the application of 0.7 V electric potential using a carbon cloth electrode. Kevin *et al.*[6] showed that the inactivation rate of *E.coli* was 2.1-4.3 times greater than to bacteriophage when drinking water contaminated with *E. coli*, *Pseudomonas aeruginosa* and bacteriophage were exposed to current ranging from 25 to 350 mA in 5s pluses. Tokuda and Nakanishi[10] were used direct current (60 mA) to inhibit the growth of *E. coli*, *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* contaminants of a bioprocess reactor. Patermarakis *et al.*[9] exposed total *Coliform* and fecal *Streptococci* in natural surface water to 2.5 mA cm^{-2} and reduced the culturable counts by an order of magnitude in 30 min .

The efficiency of electrochemical methods for disinfecting water was examined in this study. By the experiments carried out at 10 V and 135 mA current intensity, it was seen that a 5 min period is sufficient for stainless electrodes. By this way at the case of Cu-St and Al-St a little bit more time or voltage was required. When the effects of voltage, electrodes material and combination of them on disinfection were examined, as it was expected, increasing current intensity increased the efficiency. It was found that 100-300 mA is sufficient in a large scale for disinfection of water.

In an era when environmental phenomena attract a great attention, electrochemical methods can be said to be a promising cleaning and purifying method for water disinfection.

ACKNOWLEDGMENT

I would like to thank Ms Ahmadi P. for her Co-operation during the study.

REFERENCES

1. Hazen and Sawyer, 1992. Disinfection Alternatives for Safe Drinking Water. Van Nostrand Reinhold, New York, 1: 277-278.
2. Bisneto, R.T. and E. Bidoia, 2003. Effects of the electrolytic treatment on *Bacillus subtilis*, Brazilian J. Microb., 34: 48-50.
3. Kumar, S., O. Gabriel, Yen-Con Hung and P. Michael, 1999. Efficacy of electrolyzed oxidizing water for inactivation *E. coli* O157: H7, *S. enteritidis* and *L. monocytogenes*. Applied Environ. Microbiol., 65: 4276-4279.
4. Johnstone, P.T. and P.S. Bodger, 1997. High voltage disinfection of liquids. IPENZ Trans., 24: 30-35.
5. Majsunaga, T., S. Nakasona and T. Takamuko, 1992. Disinfection of drinking water by using a novel electrochemical reactor employing carbon-cloth electrodes. Applied Environ. Microbiol., 58: 686-689.
6. Kevin, P.D., M. Abbaszadegan and R.M. Maire, 2003. Comprative electrochemical inactivation of bacteria and bacteriophage. J. Wat. Res., 37: 2291-2300.
7. Sawyer, N., L. McCarty and F. Parkin, 1994. Chemistry for Environmental Engineering. 15th Edn., McGraw-Hill, Singapore, pp: 76-82.
8. Philippe, R., W. Haenni and L. Pupunat, 2003. Water treatment without chemistry. Chimia, 57: 655-678.
9. Patermarakis, G. and E. Fountoukidis, 1990. Disinfection of water by electrochemical treatment. Water Res., 24: 1491-1496.
10. Tokuda, H. and K. Nakanishi, 1995. Application of direct current to protect bioreactor against contamination. Biosci. Biotechnol. Biochem., 59: 753-755.
11. Tadashi, M.A., N. Satoshi, T. Toshihiro, B.J. Takamuka, B. Grant, N. Noriyuki and S. Koji, 1992. Disinfection of drinking water by using a novel electrochemical reactor employing carbon-cloth electrodes. Applied Environ. Microbiol., 58: 686-689.
12. Alley, E.R., 2000. Water Quality Control Handbook, McGraw-Hill, New York, pp: 3.22-3.23, 9.25- 9.29.
13. Eaton, A.D., L.S. Clesceri and A.E. Greenberg, 1995. Standard Methods for the Examination of Water and Wastewater. APHA, AWWA, WEF. 19th Edn., 9.44-9.50.