EFFECTIVENESS OF ELECTRO CHEMICAL DISINFECTION ON REMOVAL OF ESCHERICHIA COLI

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ABSTRACT

Electrochemical disinfection is convenient and very effective to kill germs in water. In this technique, there is no addition of chemicals but is based on the biocidal action of various chemical substances. Electrochemical disinfection (ED) is proved to be economical, low maintenance, and chemical-free alternative to fight pathogenic organisms present in water. The project includes a small-scale laboratory experiment, where platinum-coated electrodes were immersed in 2 L of tap water contaminated with Escherichia coli in a glass jar. Different parameters were varied to determine the optimal geometrical and operational requirements needed to kill the bacteria. The findings of the small scale experiment can be translated into real-world in large scale with further analysis and research.

Keywords:electrochemical, disinfection, E.coli.

INTRODUCTION

Nowadays, pathogens are present in drinking water. They may be able to multiply.so it is of a huge concern nowadays. Their uncontrollable growth may lead to many waterborne diseases. *Escherichiacoli* is used as an indicator to access the quality of water. In high rise buildings such as schools, hospitals etc. Legionnaires' disease in the absence of adequate control measures caused by Legionella pneumophila.[1]

The most common practices for the disinfection of tap water is done by superheat and flush, ionisation using copper, ultraviolet light, hyper chlorination. Chlorination is the most commonly used method. It provides both residual and primary disinfection. One of the major disadvantages of chlorination is that it produces trihalomethane and halo acetic acids as by products.The action of chlorine is short termed and its effectiveness reduces in presence of organics and also at high temperatures. We should also take care while transporting chlorine dioxide since it is hazardous.[2]

Electrochemical disinfection (ED) is a new concept in which a low voltage current is passed across the electrodes. It results in the formation of ozone, hydrogen peroxide etc. these are all oxidising agents. We use electrolyzed tap water because normal tap water contains small concentration of chlorine.[1]

Electrodes participate in the electrochemical process by assisting in the transfer of electrons but also by increasing and modifying the chemical reactions taking place. Hence, the electrode material directly influences the rate of generation of the oxidants necessary to inactivate the bacteria. During the past 20 years, a considerable investigation have been done on the use of titanium-based electrodes coated with lead dioxide, mixed metal oxide, platinum, iridium oxide, ruthenium oxide, zirconium dioxide, or titanium

dioxide. These electrodes combine the anticorrosion qualities of titanium with the enhanced electrochemical properties of the coating.

In the underlying investigation, the influence of electrochemical disinfection in tap water was tested on E.coli which is the common indicator. It is broadly agreed that the effectiveness of the ED process is dependent on current density, water composition, flow rate, temperature, electrode material, and cell configuration. While several studies, using a range of cell configurations, have also confirmed ED to be effective in eliminating various pathogens under controlled laboratory conditions. The effect of various operational and geometrical parameters such as voltage, electrode area, spacing of electrodes, mixing speed, volume of water on Escherichia coli is tested. Conventional methods of enumeration and detection of *E.coli* is followed.

OBJECTIVE OF STUDY

The objective of this study is to construct electro chemical disinfection apparatus and also to study the effectiveness of various operational and geometrical parameters on *E.coli*.

SCOPE OF WORK

One of the conventional method used so far is chlorination in disinfecting water. Even though the method is efficient in disinfection, it has many drawbacks. One of the main disadvantage of chlorination of water is the generation of toxic by product such as trihalomethanes and halo acetic acid. The action of chlorine is short termed and its effectiveness reduces in presence of organics and also at high temperatures. We should also take care while transporting chlorine dioxide since it is hazardous.[4]

Temperature control along with high cost and considerable CO_2 emissions are involved. The study point towards the implementation of electrochemical disinfection unit in a water treatment plant. The project we have conducted is a small scale laboratory experiment in which we suggest different parameters that is to be considered in the installation of electro chemical disinfection unit in large scale such as water treatment plant, municipal water supply system etc.[3]

METHODOLOGY

The different materials used for the construction of the electrochemical disinfection unit is listed below:

MATERIALS USED FOR THE DISINFECTION UNIT

• Arduino Board – Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input or output pins that may be interfaced to various expansion boards and other circuits. In this experiment we have used arduino for adjusting the speed of stirrer.

Fig 7.1: Arduino (www.arduino.cc.com)

• H bridge- It is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used to allow DC motors to run forward or backwards.

• DC motor – A DC motor is a rotary electrical machines that converts direct current electrical energy into mechanical energy. The dc motor used was of 1000 rpm. The DC motor was used to adjust the speed of the stirrer.

Fig 7.2: DC motor (www.google.com)

- Jumper wire-It is an electric wire or group of them in a cable with a connector or pin at each end, which is normally used to interconnect the components of a breadboard or with other equipment or components without soldering.

Fig 7.3 Jumper wire (www.google.com)

- Potentiometer-It is a three terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.

Fig 7.4: Potentiometer (www.google.com)

- Stirrer-The stirrer used was a fan type plastic stirrer which was connected to a plastic stem. The material was selected so as to avoid any reaction when immersed in water for the electrochemical disinfectionprocess. The speed at which stirrer operated could be adjusted accordingly.
- Glass jar-The experiment was conducted in a typical glass jar of 3L capacity. As simple sterilization was adopted for the prior purification of materials required, instead of autoclaving, simple glass jar was sufficient for the disinfection process.

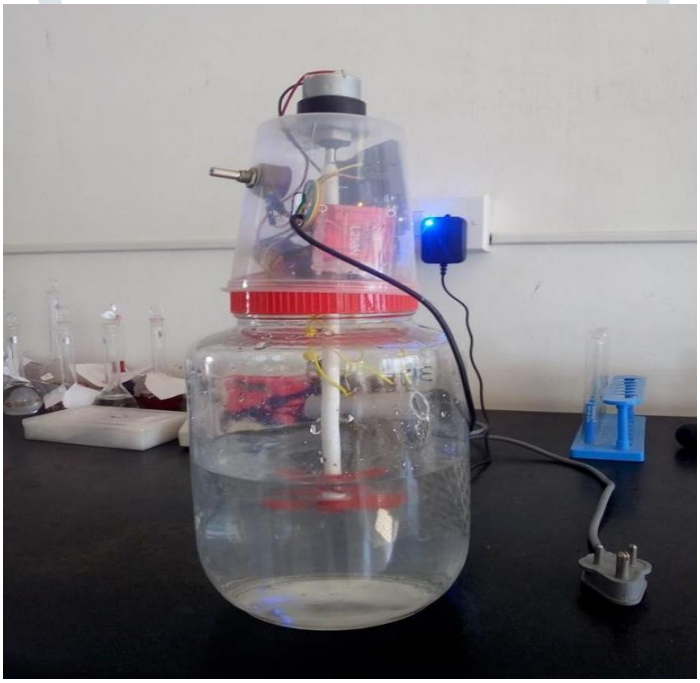

Fig 7.5: ED Unit

WATER USED IN THE STUDY

- The water used in the study was well water which is used for house hold works. The water sample used was not chlorinated hence, the effectiveness of electrochemical disinfection could be evaluated efficiently.

BACTERIA USED

- The bacteria used in experiments were *E.coli.* It is the most commonly used indicator organism to detect fecal contamination. The final enumeration of *E.coli* was determined using Multiple TubeFermentation technique.

ELECTRODE USED

- The electrodes used were platinum coated titanium electrode of size 100mm x 20mm.The platinum plating of thickness 3 microns was provided on both sides. In order to increase the surface area of electrode, we used mesh type instead of using plate type. In our experiment we are using 6 pieces of electrodes. According to studies conducted by Alexander Kraft with different electrodes materials the platinum material was found to be long lasting and able to produce more oxidants.[1]

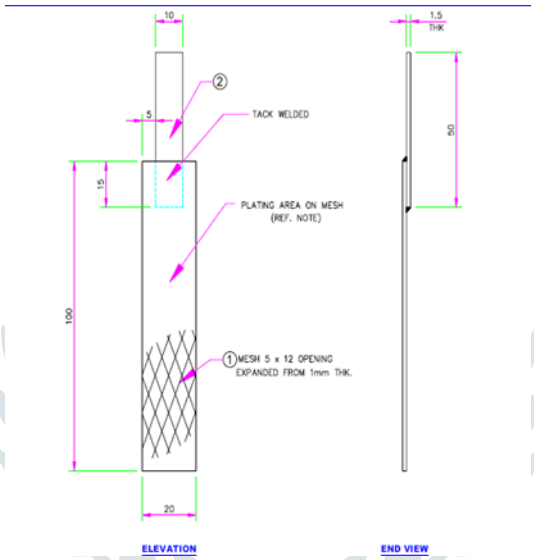

Fig 7.6: Drawing of electrode used for the manufacturing of Platinum coated Titanium Electrode.

DETERMINATION OF TOTAL COLIFORMS

The determination of E.coli was done by Multiple Tube Fermentation Technique.

Principle

The MPN test is based on the most probable number of coliform organism. The coliform group has the ability to ferment lactoseor lauryl tryptose broth and produce gas. This offers a simple test of presence of coliform. However some other organism also ferment broth under certain conditions and therefore additional growth reactions must be carried out to confirm the presence of coliform. After presumptive test the production of gas in the brilliant green lactose bile confirms the presence of coliform.

Procedure

1. Presumptive test

Lactose Broth or lauryl tryptose broth to be used in the Presumptive test.

- Inoculate a series of fermentation tubes with appropriate graduated quantities of water to use. The concentration of nutritive ingredients in the mixture of medium should confirm to the specification.
- The portions of sample used for inoculating lactose or lauryl tryptosebroth fermentation tubes will vary in size and number with character of water to be used for examination
- Usually decimal multiples and submultiples of 1ml of the sample is selected. Inoculate 10 ml portion of each water sample provided into different one or three large tubes containing 10ml of lactose which has been prepared with twice normal concentration of constituents for allow for dilution. Inoculate 1 ml and 0.1 ml of water into small tubes of single strength lactose.
- Incubate the inoculated fermentation tubes at 35 ^{0}C. At the end of 24 hrs. Shake each tube gently and examine and if no gas is formed repeat the test at end of 48 hrs.
- Record the presence or absence of gas formation at each examination of tubes.
- Formation of gas within 48 hrs. in any fermentation tube indicates positive test

Confirmed test

- Lactose may be used for primary fermentation in presumptive test to avoid false positive results
- Brilliant green lactose bile fermentation tubes are used in confirmed test
- Submit all primary fermentation tube showing any amount of gas at the end of 24hr incubation of confirmed test
- Gently shake the primary fermentation showing gas formation and with sterile metal loop, transfer one loop full of medium to a fermentation tubcontaining brilliant green lactose bile
- Inoculate the inoculated lactose bile broth tube for 48hrs at 35C 6. Formation of gas within 48 hrs in any fermentation tube indicates positive test.
- If no gas is formed, it is negative test.

MPN DETERMINATION FROM MULTIPLE TUBE TEST

NUMBER OF TUBES GIVING POSITIVE REACTION OUT OF			MFN Index per 100 ml.	95 PERCENT CONFIDENCE LIMITS	
3 of 10 ml. each	3 of 1 ml. each	3 of 0.1 ml. each		Lower	Upper
0	0	1	3	<0.5	9
0	1	0	3	<0.5	13
1	0	0	4	<0.5	20
1	0	1	7	1	21
1	1	0	7	1	23
1	1	1	11	3	36
1	2	0	11	3	36
2	0	0	9	1	36
2	0	1	14	3	37
2	1	0	15	3	44
2	1	1	20	7	89
2	2	0	21	4	47
2	2	1	28	10	150
3	0	0	23	4	120
3	0	1	39	7	130
3	0	2	64	15	380
3	1	0	43	7	210
3	1	1	75	14	230
3	1	2	120	30	380
3	2	0	93	15	380
3	2	1	150	30	440
3	2	2	210	35	470
3	3	0	240	36	1,300
3	3	1	460	71	2,400
3	3	2	1,100	150	4,800

WHO Chart For Standard Method Of Examination of Water

CONCLUSION

Electrochemical water disinfection has many advantages compared with conventional disinfection technologies. It has proven its reliability in several practical applications, mainly for the disinfection of drinking water, swimming pool water and industrial cooling water. Electrochemical water disinfection has also been used or tested for the reduction of bacterial contamination in dental water supplies, and for the disinfection of contact lenses and ion exchange resins etc.[5] However, only a few electrochemical water disinfection products are currently available on the market. This is due to the relative unfamiliarity of the technology, and to fierce market competition with other technologies. Eventually, the cost and performance advantages of electrochemical technology should lead to its wider use. RuO2 and/or IrO2-coated electrodes are the best suited to disinfection based on hypochlorite generation.[1] This is due to their high production efficiency for hypochlorite from water with a very low chloride content. Pt is the favoured electrode material for oxygen production from natural waters. Pt electrodes are also the most stable. For the production of ozone and hydrogen peroxide, platinum group metal electrodes are not the first choice, being outperformed by carbon electrodes, i.e. doped diamond for ozone, and graphite for hydrogen peroxide production.[22]

REFERENCES

[1] G. Cossali,et al., "Inactivation of E. coli, Legionella, and Pseudomonas in Tap Water Using Electrochemical Disinfection", ASCE, J. Environmental Engineering; Volume 142, Issue 12, June 2016.

[2] G.Chen et.al, "Electrochemical technologies in wastewater treatment", Sciencedirect, Separation and Purification Technology; Volume 38, pp.11-41, October 2003.

[3] A.Kraft, "Electrochemical Water Disinfection: A Short Review", Platinum Metals Review, Volume 52, Issue 3, July 2008.

[4] Y. Delaedt et.al. "The impact of electrochemical disinfection on Escherichia coli and Legionella pneumophila in tap water", Sciencedirect, Microbial Research; Volume 67, Issue 4, pp.652-659, March 2007.

[5] M.I. Kerwick et al., "Electrochemical disinfection, an environmentally acceptable method of drinking water disinfection?" Sciencedirect, Electrochimica Acta; Volume 50, pp.5270–5277, June 2005.

[6] V. G. Sister et al., "Electrochemical method for disinfection of hot water supply systems", Chemical and Petroleum Engineering, Volume. 49, pp. 9–10, January, 2014.

[7] X. Y. Li,et.al., "Electrochemical Wastewater Disinfection: Identification of Its Principal Germicidal Actions", ASCE,Journal of Environmental Engineering; Volume 130, Issue 10,pp.1217-1221., October 2004.

[8] S.C. Edberg et al., "Escherichia coli: the best biological drinking water indicator for public health protection", Journal of Applied Microbiology; 2000.

[9] J. D.V Elsas et al., "Survival of Escherichia coli in the environment: fundamental and public health aspects", International Society for Microbial Ecology; Volume 5, pp.173- 183, 2011.

[10] N. N. Barashkov et al., "Chlorine-Free Electrochemical Disinfection of Water Contaminated with Salmonella typhimurium and E. coli B", American Chemical Society; pp.21-33, December 20, 2011.

[11] Garry R. Buettner and Freya Q. Schafer., "Free Radicals, Oxidants, and Antioxidants", Teratology; 2000.

[12] G. Patermarakis and E. Fountoukidix., "Disinfection of Water by Electrochemical Treatment", Water Resource; Vol. 24, Issue No. 12, pp. 1491-1496, 1990.

[13] Ivan Sondi and Branka Salopek-Sondi, "Silver nanoparticles as antimicrobial agent: a case study on E. coli as a model for Gram-negative bacteria", Sciencedirect, Journal of Colloid and Interface Science; Vol. 275, pp. 177–182, 2004.

[14] Annie Rompre et al., "Detection and enumeration of coliforms in drinking water: current methods and emerging approaches", Sciencedirect, Journal of Microbiological Methods; Vol. 49, pp.31–54, 2002.

[15] Carlos A. Martinez-Huitle and Enric Brillas, "Electrochemical Alternatives for Drinking Water Disinfection", Angewandte Chemie Institute; Vol.47, 2008.

[16] Henry Bergmanna and Savas Koparal, "The formation of chlorine dioxide in the electrochemical treatment of drinking water for disinfection", Sciencedirect, Electrochimica Acta; Vol.50, pp.5218–5228, 2005.

[17] Joonseon Jeong et al., "The effect of electrode material on the generation of oxidants and microbial inactivation in the electrochemical disinfection processes", Sciencedirect, Journal of water research; Vol. 43, pp.895–901, 2009.

[18] Chuanping Feng et al., "Water disinfection by electrochemical treatment", Sciencedirect, Bioresource Technology; Vol. 94, pp. 21–25, 2004.

[19] S.N. Hussain et al., "Disinfection of water by adsorption combined with electrochemical treatment", Journal of Water Research; Vol.43, January 2014.

[20] Jeyong Yoon et al., "Inactivation of Escherichia coli in the electrochemical disinfection process using a Pt anode", Sciencedirect, Chemosphere; Vol. 67, pp. 652–659, 2007.

[21] A.M. Polcaro et al., "Characterization of a stirred tank electrochemical cell for water disinfection processes", Sciencedirect, Electrochimica Acta; Vol. 52, pp.2595–2602, 2007. [22] M.A. Rodrigo et al., "Electrochemical technologies for the regeneration of urban wastewaters", Sciencedirect, Electrochimica Acta; Vol. 55, pp.8160–8164, 2010.