

# A Comparative Study on Disinfection of Water by Electrochemical Treatment Using Coated and Uncoated Titanium Electrodes

Deepthi B.P and Dr K.S Lokesh

## Abstract

River Water, highly contaminated with *Coliforms* and *Faecal streptococci*, was electrochemically treated with titanium electrodes. Electrolysis was done using both coated and uncoated titanium electrodes without employing any additives for a period of 90 min at every 4V interval till 32 V. For uncoated titanium electrodes, at cell voltage of 32V, current density of 0,0032 A/cm<sup>2</sup> microbial inactivation was 92% for Total Coliform(TC), Faecal Coliform(FC) - 89% and Faecal Sterptococci (FS) - 84% for 90 min of electrolysis and power required is 0,0051 kWh/m<sup>3</sup>. For coated titanium electrodes at an cell voltage of 16V and current density of 0.006 A/ cm<sup>2</sup> inactivation of TC was 99.6%, FC - 99.6% and FS - 96% for 75 min of electrolysis and the power required is 0.0035 kWh/m<sup>3</sup>. Residual disinfection was significant between 5 and 15min and decreases with time because of short lived and energy rich oxidants that act as germicidal agents. Compared to uncoated electrodes, coated electrodes showed the promising result since it has better conducting capacity, less dissolution of electrodes and thus more durable.

**Key words:** Coliforms, Electrochemical process, Inactivation, Reservoir effect, Titanium electrodes

## I. INTRODUCTION

Disinfection is an important step in ensuring that water is safe to drink. Water disinfection means the removal, deactivation or killing of pathogenic microorganisms. Disinfection can be attained by means of physical or chemical process. In chemical processes, disinfecting substances such as ozone, chlorine, sodium hypochlorite or chlorine dioxide are added to the water to be treated. A frequent drawback of the chemical processes is unwanted side reactions of the disinfectants with substances present in the water. These reactions lead to disinfection by-products, some of which are considered dangerous [8],[6],[7]. There are also hazards in producing, transporting and handling large amounts of such substances as chlorine and ozone. In physical disinfection processes the microorganisms are removed or killed by means of irradiation with ultraviolet or ionising radiation, heating to elevated temperatures, ultrasound, or separation through membrane filtration. The main drawback of the physical disinfection methods is the lack of a reservoir effect. These processes are only effective in the immediate surroundings of their operating devices [7]. As compared with other chemical disinfection methods, the advantages of electrochemical water disinfection are obvious: no transport, storage and dosage of disinfectants are required. Electrochemical water disinfection shows a reservoir effect and is often more cost-effective and requires less maintenance than other disinfection methods [1]. Electrochemical treatment of water can destroy a large variety of microorganisms. Approximately 40 species of microorganisms varying in size from Viruses through bacteria and algae to relatively large species such as euglena have been successfully treated [9],[2],[3],[5].

In the present study river water highly contaminated with Total coliforms , Faecal coliforms and Faecal streptococci, was treated in an electrochemical cell with both coated and uncoated titanium electrodes, without employing additives. The objectives were to verify the effectiveness of the process and to compare the efficiency of coated and uncoated

titanium electrodes in the electrochemical inactivation process.

## II. MATERIALS AND METHODS

Kapila River water, which is the main source of municipal water for Nanjangud town, near Mysore, Karnataka, India was used for the experiments before it has undergone any treatment.

### A. Electrochemical (EC) treatment

The experimental setup employed consisted of an electrochemical cell with two Titanium electrodes on a magnetic stirrer. The Titanium electrodes, 5 X 5cm, were suspended in an electrochemical cell containing the contaminated water sample parallel to each other at a distance of 1cm apart. The electrodes were connected to the positive and negative terminals of DC power supply unit. The experiments were carried out on batch modes at varying Cell voltage and current density. Samples were retrieved at regular intervals of time.

Before beginning the treatment of contaminated water, all necessary laboratory apparatus were disinfected in an autoclave. A volume of 1000ml of water sample was placed in the electrochemical cell. Experiment was carried out at a lab temperature and the water, during electrochemical treatment, was magnetically stirred at a moderate rate in order to ensure complete mixing. Experiments were performed in a monopolar batch reactor with two titanium electrodes (anode and cathode) and were connected to DC power supply. Experiments were conducted for both uncoated and coated titanium electrodes for voltage rang of 4 to 32V. The volume of the solution in each batch was 1Litre. EC experiments were performed for 90 min and for each run, samples were retrieved at every 15min. Multiple Tube Fermentation Technique (MTFT) was carried out for bacteriological analysis.

### III. RESULTS AND DISCUSSION

Batch EC was carried out for microbial density of TC 45,000; FC 900 and FS 900 MPN/100 mL, at 4V interval till 32V for a period of 90 min. Samples were retrieved at every 15 min for bacteriological analysis. Fig1(a-c) shows the microbial inactivation at different cell voltages using uncoated titanium electrode. Better inactivation efficiency was observed at 32V, at a current density of 0.0032A/cm<sup>2</sup>, power of 0.0052 kWh/m<sup>3</sup> for an electrolysis duration of 90 min. At the end of 90 min, electrolysis microbial density was TC - 1750, FC - 93, FS - 143 with inactivation efficiency of 96%, 89% and 84% respectively. Fig.2 (a-c) shows the microbial inactivation at different cell voltages with coated titanium electrodes. Coated titanium electrodes showed promising results when compared to uncoated titanium electrodes. The optimum electrolysis time for coated electrodes was 75min, cell voltage of 16V, current density of 0.006 A/cm<sup>2</sup> and power of 0.0035 kWh/m<sup>3</sup>, under the above condition density of microbes were TC - 150, FC - 3, FS - 36 with inactivation efficiency of 99.6 %, 99.6% and 96% respectively. Uncoated Titanium Electrodes, have shown the titanium electrode consumption from 0.0004 to 0.0127g where as coated electrodes have shown lower electrode consumption from 0.0006 to 0.0061g.

Increase in cell voltage increases the rate of oxidation, thus forming the reactive species. Short lived free radical species such as •OH, O•, H<sub>2</sub>O• and more stable substances such as Cl<sub>2</sub>, ClO<sup>-</sup>, HClO, O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub> are the major inactivating ions. Reactive Oxygen Species such as •OH, O•, H<sub>2</sub>O•, O<sub>3</sub> or H<sub>2</sub>O<sub>2</sub> because of their high oxidation potential make them more effective than Chlorine in killing all kinds of microorganisms [10]. Microbial inactivation occurs through two distinct stages. One is the direct oxidation at the electrode surface and the other is indirect oxidation mediated by reactive oxidants generated from the water discharge and two mechanisms can occur simultaneously [4].

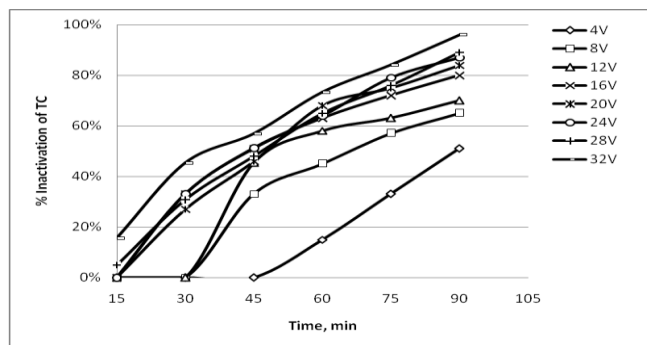


Fig.1(a) Percentage Inactivation of TC - Uncoated Titanium Electrode

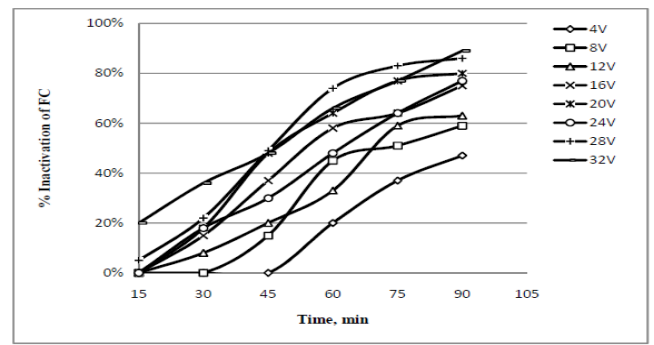


Fig.1(b) Percentage Inactivation of FC - Uncoated Titanium electrodes

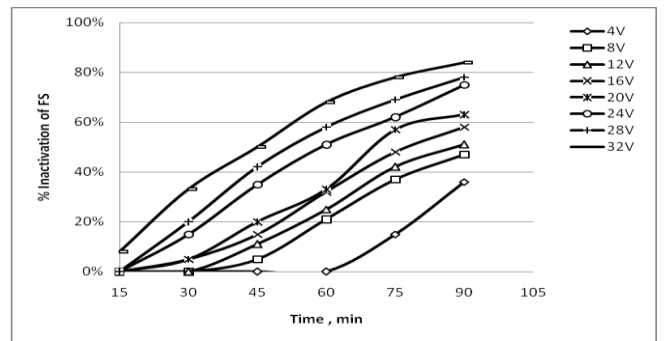


Fig.1(c) Percentage Inactivation of FS - Uncoated Titanium Electrodes

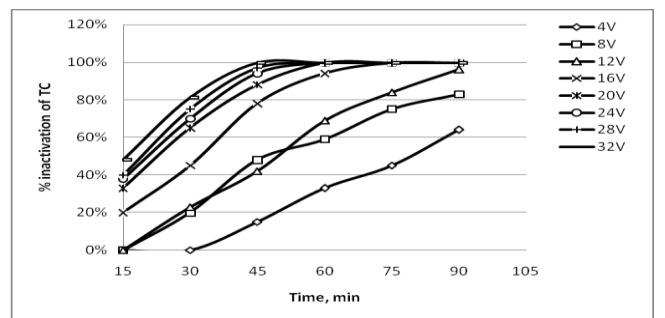


Fig.2(a) Percentage Inactivation of TC - Coated Titanium Electrode

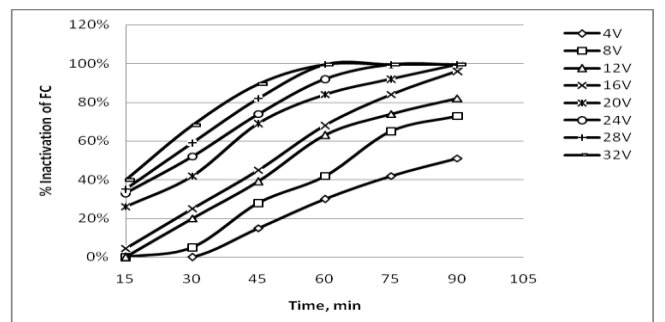


Fig.2(b) Percentage Inactivation of FC - Coated Titanium Electrodes

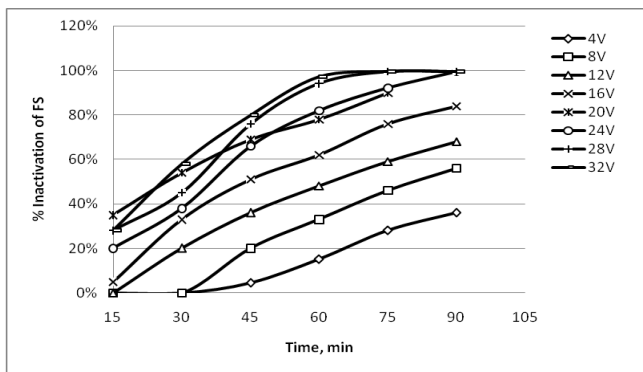


Fig.2.(c) Percentage Inactivation of FS - Coated Titanium Electrodes

A. Residual Disinfection of Water

Water sample, prior to contamination was treated with a cell voltage of 32V for 90 min and was mixed with equal amount of contaminated water. Contaminated water was mixed with treated water at various time intervals i.e., 5, 10, 15, 30, 45 and 60 min immediately after electrolysis. Residual Disinfection Profile for uncoated and coated titanium electrodes is shown in Fig 3 and 4. Residual disinfection is high at 5 min and it has decreased with time. This is because of short lived oxidants that act as germicidal agents.

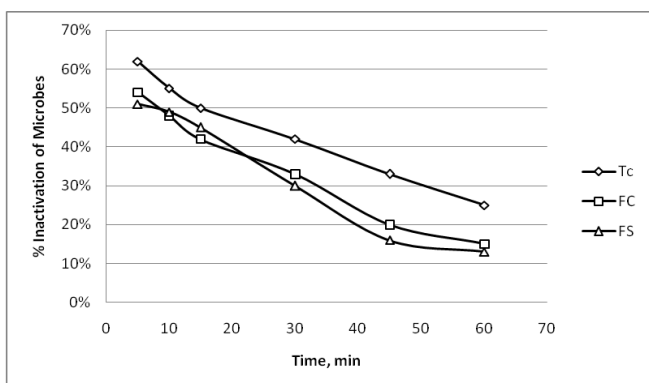


Fig.3 Residual Disinfection Profile - Uncoated Titanium Electrode

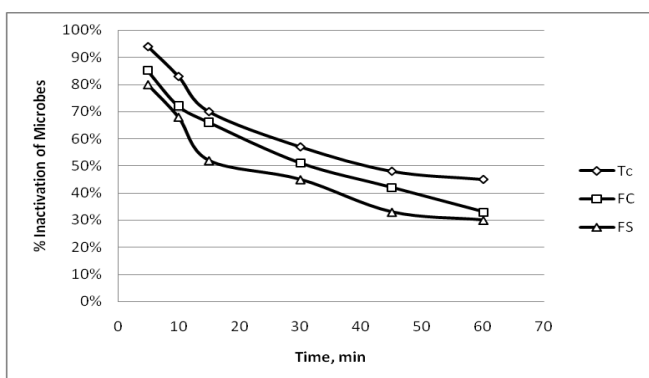


Fig.4 Residual Disinfection Profile - Coated Titanium Electrodes

B. Electrochemical Kinetics

Fig.5 shows the effect of voltage on the rate of reaction during the electrolysis time for uncoated titanium electrodes. At lower volts the microbial inactivation was not much

efficient; hence to study the reaction rate, higher optimal volt was taken into the consideration. The rate of reaction also increases with increase in voltage. At 32V the reaction rates for TC, FC and FS were 0.016min<sup>-1</sup>, 0.010min<sup>-1</sup> and 0.011 min<sup>-1</sup> respectively. Fig.6 shows the effect of voltage on the rate of reaction during the electrolysis time for coated titanium electrodes. At 16V the reaction rates for TC, FC and FS were 0.034min<sup>-1</sup>, 0.035min<sup>-1</sup> and 0.029 min<sup>-1</sup> respectively.

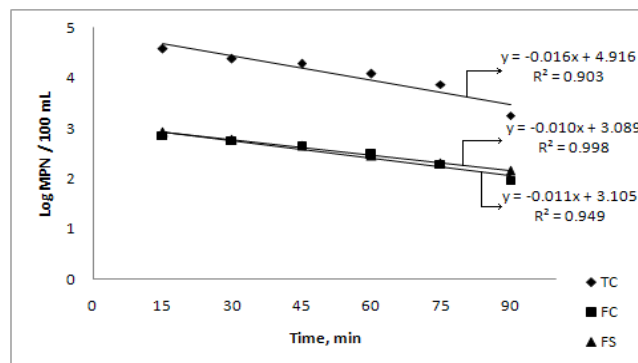


Fig.5. Rate of Inactivation - Uncoated Titanium Electrodes

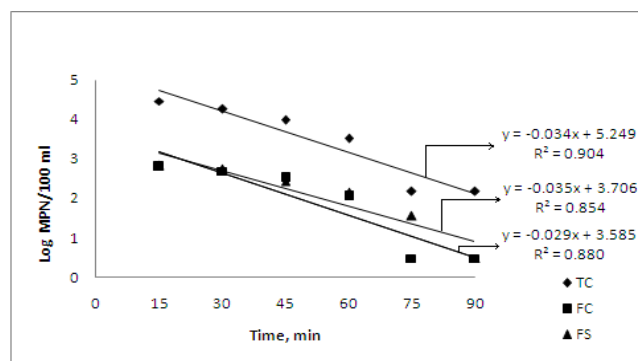


Fig.6. Rate of Inactivation - Coated Titanium Electrodes

IV. CONCLUSIONS

Electrochemical water disinfection has many advantages compared with conventional disinfection technologies. From the present work, the result obtained shows that, with uncoated electrodes, over 85% of microbial inactivation were recorded for TC, FC and FS at a current density of 0.0032 A/cm<sup>2</sup> and power of 0.0052 kWh/m<sup>3</sup> for 90 min of electrolysis time. When coated electrodes was used, significant microbial inactivation recorded for TC, FC and FS was over 98% for a 75 min of electrolysis time at a low current density of 0.006 A/cm<sup>2</sup> and power 0.0035 kWh/m<sup>3</sup>. Residual disinfection capacity was examined for optimum operating condition and it was observed that residual disinfecting capacity was significant between 5 to 15 min and decreases with time because of short lived and energy rich oxidants that act as germicidal agents. With the increase of cell voltage, current density and time, the efficiency of inactivation was significant, since the rate of oxidation increases with time and current density. Compared to uncoated electrodes, coated electrodes showed the promising result since it has better conducting capacity, less dissolution of electrodes and thus more durable and efficient.

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