Purification of Floodwater by Electrolysis

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Abstract

An adequate supply of pure water is absolutely essential to human existence. During floods, water is available in adequate quantity, but the quality is often not suitable for drinking or cooking purposes. The goal of the study was to develop an easier, cheaper and faster technique of water purification. Oxygen ions are well known for their high reactivity. An attempt has been made to use oxygen ion to disinfect water. If a container of water is subjected to electrolysis, hydroxyl and hydronium ions are produced which move through the liquid from one electrode to another. It is expected that these ions, particularly the hydroxyl ion, will come across bacteria and react with it chemically to eliminate it. The process is similar to the mechanism of disinfecting water using halogen tablets. Considerable reduction in indicator organisms was obtained through treatment of floodwater with alum followed by electrolysis. The results obtained are not conclusive but are encouraging.

INTRODUCTION

Halogen tablets are widely used to purify drinking water. When a halogen tablet is dissolved in water, chlorine ions are generated, which are strong oxidizing agent. Chlorine ions are of high toxicity and kill bacteria on contact. Based on this basic idea of oxidation of the bacteria, an attempt has been made to evaluate the effect of hydroxyl ion, generated through electrolysis, on bacteria. The aim was to develop a simple water purification technique, based on electrolysis, which could be used in flood-affected areas in Bangladesh. Bangladesh experiences flood almost every year and its magnitude often reaches a catastrophic level. In most of the situations, halogen tablets are not available in the village shops. People suffer from shortage of drinking water and diarrheal diseases take an epidemic form. During floods, although water level rises significantly, electricity supply remains uninterrupted in many places and electrolysis may be adopted for purification of water.

THEORY OF THE PROPOSED TECHNIQUE

Pathogens

Pathogens are organisms capable of infecting, or of transmitting diseases to humans. These organisms are not native to aquatic systems and usually require an animal host for growth and reproduction. They can, however, be transported by natural water systems, thus becoming a temporary member of the aquatic community. Waterborne pathogens include species of bacteria, viruses, protozoa and helminths (parasitic worms).

Pathogen Indicators

Analysis of water for all the known pathogens would be a very time consuming and expensive proposition. Purity of water, from bacteriological perspective, is usually checked through the indicator organisms. Most of the waterborne pathogens are introduced through fecal contamination of water. There are other coliform groups, which flourish outside the intestinal tract of animals. These organisms are native to the soil and decaying vegetation and are often found in water that was in recent contact with these materials.

It is the usual practice to use:

- The total coliform (TC) group as indicators of the sanitary quality of the drinking water.
- The fecal coliform (FC) group as indicators of wastewater effluents.

The test for total coliform organisms employs slightly different culture media and lower incubation temperature than those used to identify fecal coliform organisms.

The membrane-filter technique stated in the Standard Methods (Greenberg et al., 1999) was used to determine the degree of contamination of water. This technique is popular with environmental engineers and gives direct count of coliform bacteria. In this test, a portion of the sample is filtered through a membrane, the pores of which do not exceed 0.45 μm. Microorganisms are retained on the filter that is then placed on selective media to promote growth of coliform bacteria while inhibiting growth of other species. The membrane and media are incubated at the appropriate temperature for 24 hours, allowing coliform bacteria to grow into visible colonies that are then counted. The results are reported in numbers of organisms per 100 mL of water.

EXPERIMENTAL SETUP

Preparation of the Electrodes

Since, the purification process was based on electrolysis, the success of the study greatly depended on having good and reliable electrodes. In this study, nickel-coated galvanized iron sheets were used as electrodes. The nickel coating was used to reduce corrosion of soft iron when electrolysis is performed. Approximately 3 μm thick nickel coating was provided on each iron sheet. The dimension of the electrodes and the beaker was interrelated. Measurements for the electrodes are given in the Fig. 1.

Twelve pieces of electrodes were prepared at a local galvanizing factory by applying appropriate nickel coating. Two important factors were considered during the fabrication of the electrodes. These were: (1) It is essential that the plates and the coatings should be as smooth as possible. It is likely that excessive corrosion would occur if there are bends or scratches on the plates (electrodes); and (2) A thick and uniform nickel coating is essential in reducing rapid degradation of electrodes.

Preparation of the Reaction Vessel

A specially designed reaction vessel was constructed to perform the electrolysis of floodwater. A 600mL perspex box, fitted with guide slots on the shorter sides for electrodes, was constructed for the above purpose. The dimension of the beaker is shown in the Fig. 2.

Experimental Setup and Procedure

The experimental setup included the following equipment:

- Auto-transformer for variable ac voltage

- Multi-meter to measure current
- Voltmeter
- Test tubes and beakers to perform chemical analysis
- Incubators

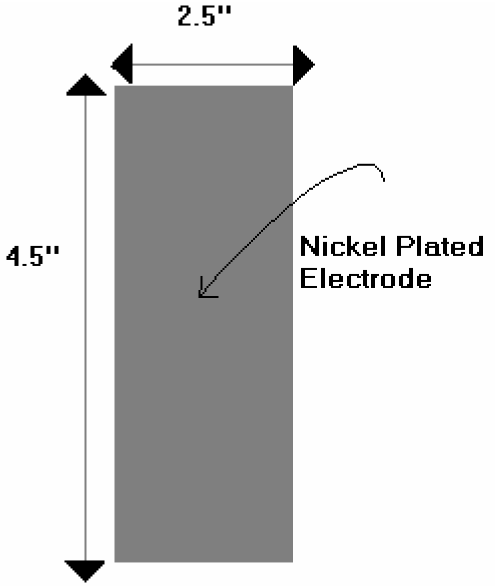

Figure 1: Dimension of the Electrode

TREATMENT OF FLOODWATER

During the course of the experimental setup, the floodwater receded from around the Dhaka city. Thus, actual floodwater samples could not be collected, instead samples were collected from the pond at the Suhrawardhy Uddayan and the surface drains at the Dhaka Medical College Hospital (DMCH). Synthetic samples were prepared from these samples to substitute for the floodwater. It was suspected that the collected samples were extremely polluted with pathogens and indicator organisms. Thus, very small amount of this sample was added to a 17-liter bucket full of tap water, which was considered as the stock floodwater sample for the purpose of this experiment. From this stock each time 600mL was used at different stages of the experiment. Prior to each set of experiment, initial concentrations of the indicator organisms, TC and FC, were determined by the Membrane Filtration technique. However, since the initial concentrations of the indicator organisms were suspected to be very high the synthetic sample was diluted prior to testing. Otherwise, the total number of the colony developed on the membrane filter would be so high that it would be impossible to count them.

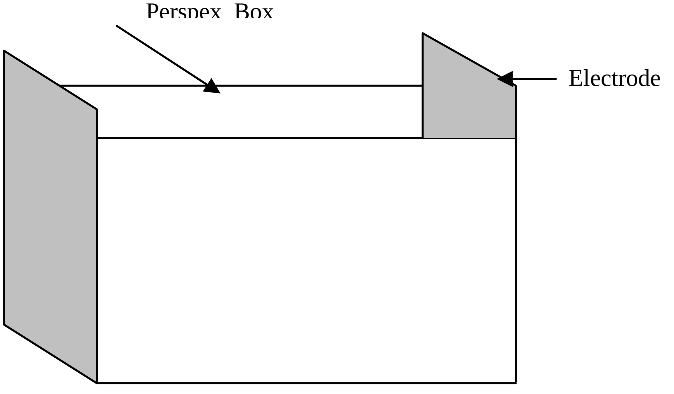

Figure 2: Schematic Diagram of the Electrolytic Cell Used for Purification of Water

The electrodes were placed in the beaker and were clamped by the side bands. Two types of power supplies (AC and DC) were used. For AC supply the Variac was used, whereas, for DC supply the regulated power supply was used. Ammeter and voltmeter were used to monitor current and voltage, respectively. A constant current was passed through the series circuit arrangement for a pre-designated period. Time span was recorded using a stopwatch. After the synthetic sample was treated with electricity for the pre-designated period a specific amount of sample was extracted from the reaction vessel for analysis of TC and FC using Membrane filtration. Figure 3 shows the schematics of the entire process.

The second step of the experiment involved the application of locally available household chemicals such as common salt (NaCl) and Alum [$Al_2(SO_4)_3$, $2H_2O$] to the synthetic floodwater followed by electrolysis. Initially, 50 gm of common salt was added to the synthetic floodwater and was thoroughly mixed until it was completely dissolved in water. Then the sample was poured into the reaction vessel and treated with AC power as before. A small amount of the supernatant liquid was extracted from the vessel and processed as before for analysis.

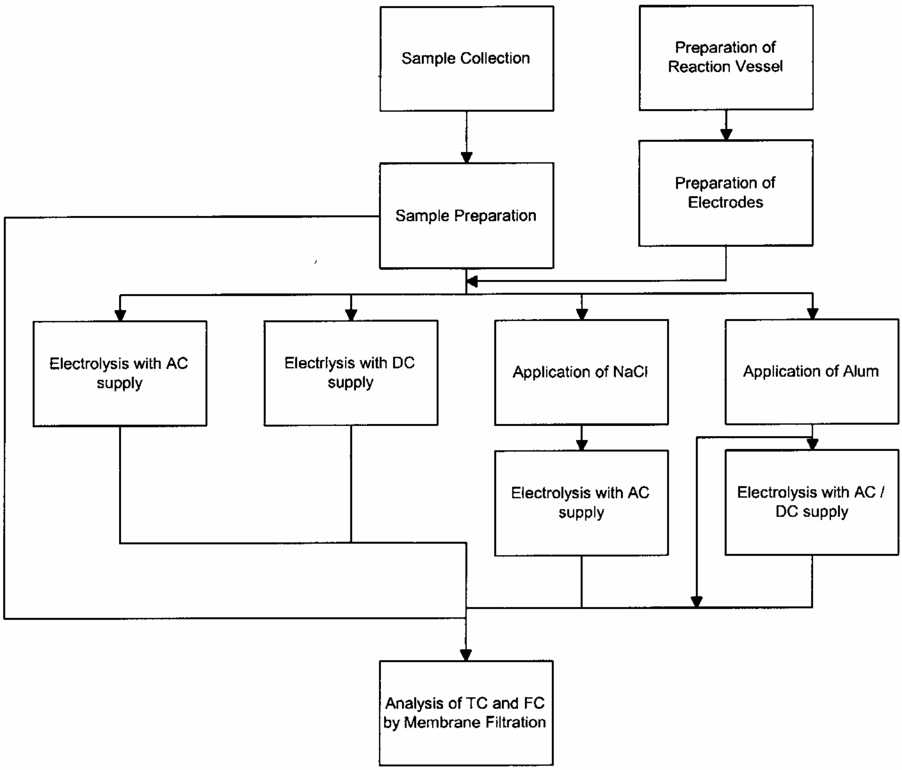

Figure 3: Schematic diagram of the steps involved in treatment of floodwater by electrolysis

Following the above step another stock of the synthetic sample was dosed with Alum (125 mg/L) and vigorously mixed. Then to hasten the flocculation process the mixed solution was stirred slowly. This allowed the smaller flocs to come into contact with each other and form larger flocs. The flocs were then allowed to settle for 30 minutes. The supernatant liquid was then poured into the reaction vessel and treated with AC supply. A small amount of treated water was then extracted as before for analysis of TC and FC. The entire procedure was repeated with DC power supply.

Floodwater samples were also collected from the Buriganga River during the 1998 flood and laboratory experiments were conducted using alum and electrolysis as before. Water near the banks of the river is likely to be highly polluted and aesthetically unacceptable. Hence, floodwater sample was collected from the middle of the river.

RESULTS AND DISCUSSION

The results of different treatment options of synthetic water samples are presented in Table 1. This table shows that electrolysis and combination of electrolysis and chemical addition did not prove to be very effective with extremely contaminated synthetic samples. Table 1 indicates that even after dilution the synthetic samples remained highly polluted with indicator organisms.

Table 1: Results of Different Treatment Options of the Synthetic Sample

Power Supply	Condition	Time	Current	Voltage	Temp	TC	FC
		(min)	(amp)	(volts)	(°C)	#/100mL	#/100mL
Direct Current	No Chemicals	0	--	--	29	28,000	1,300
		5	0.50	38	44	5,400	700
Alternating Current	Before adding NaCl	0	--	--	29	56,000	40,000
		5	1.01	117	43	9,600	30,000
	After adding NaCl	0	--	--	29	56,000	40,000
		5	1.00	60	34	7,000	1,100
Direct Current	Before adding Alum	0	--	--	29	72,000	32,000
		5	1.00	150	45	10,400	3,200
	After adding Alum	0	--	--	29	4,400	1,200
		5	0.50	81	32	800	400
Alternating Current	Before adding Alum	0	--	--	24	TNTC*	--
		5	1.02	187	42	8,000	--
	After adding Alum	0	--	--	24	TNTC*	--
		5	1.01	187	46	500	--

*TNTC = Too Numerous To Count

When the synthetic sample was treated with only the direct current about 80-85% removal of Total Coliform was achieved, whereas, the same for the Fecal Coliform was about 50-90%. It was also observed that the removal rate of both the TC and FC increase with the increase of current flow. On the other hand, the removal rates for TC and FC using alternating current were 83% and 25%, respectively.

The second step of the experiment involved addition of locally available chemicals such as common salt and alum followed by electrolysis. No significant improvement in reduction of TC was observed (compared to the electrolysis alone) when NaCl was added to the synthetic sample followed by electrolysis with AC supply. On the other hand, alum coagulation of the synthetic sample alone removed about 95% of both TC and FC. Further reduction of about 80% and 75% of TC and FC, respectively of the synthetic samples pretreated with alum were achieved through electrolysis using DC supply. Although reduction of TC and FC through the application of AC supply following alum coagulation was achieve, the actual rate of removal could not be established due to excessively high initial concentrations of the indicator organisms.

The above experiments on highly polluted synthetic samples indicated that the aforementioned approach has enormous potential for treating floodwater for domestic use. Electrolysis of the floodwater sample was performed using AC supply following alum coagulation. Table 2 shows the results of the laboratory analysis of the actual flood sample. It was observed that the initial concentrations of the TC and FC of the floodwater sample were considerably lower than the synthetic sample (Table 2). About 30% reduction in TC and almost complete removal of FC was obtained following alum coagulation. A complete removal of total coliform was observed when the floodwater sample pretreated with alum was electrolyzed using AC supply. However, it should be noted that the temperature of the sample increased considerably when AC supply at high voltage was applied. This increase in temperature may have contributed to the reduction of some of the total coliform of the pretreated sample.

Table 2: Results of Electrolysis Treatment of Floodwater Sample

Power Supply	**Condition**	**Time**	**Current**	**Voltage**	**Temp**	**TC**	**FC**
		(min)	**(amp)**	**(volts)**	**(°C)**	**# 100mL**	**#/100mL**
Alternating Current	Initial	--	--	--	32	250	50
	30 min. after adding Alum	--	--	--		170	0
	After applying current	0	--	--	32	170	0
		5	1.02	203	53	0	0

CONCLUSIONS

In this study a limited number of experiments were performed due to resource and time constraints. Although no concrete recommendations can be made based on such a limited study, the results obtained are encouraging. Thus, it is suggested that a more comprehensive study be conducted involving actual floodwater samples. It is also recommended that application of high frequency power supply for treatment of floodwater be studied.

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