International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com‖ Volume 2 Issue 2‖ February 2016 ‖ PP 23-33

Electrolytic Method for Deactivation of Microbial Pathogens in Surface Water for Domestic Use

Piyush Mahore [1], Pramod R. Chaudhari [2], Pravin Charde [1]
[1] *Sevadal Mahila Mahavidyalaya and Research Academy, Sakkardara Chowk, Nagpur, India*
[2] *CSIR-National Environmental Engineering Research Institute, Nagpur, India.*
Corresponding author: Pramod R. Chaudhari,

Abstract: Electrochemical or electrolytic disinfection is one of the emerging technologies for treating drinking water and wastewater. This method gained much attention, especially because of its practical feasibility as there is no need for addition of chemicals or generation of toxic byproducts. In addition to this, the operational cost is also low. This work is thus aimed at studying the deactivation of waterborne pathogens from lake water by electrolytic disinfection. The electrolytic disinfection unit (EDU) was designed and examined for efficiency of deactivation of microbial pathogens in raw lake water. The batch scale experiments were performed to investigate the effect of aluminum electrodes with direct current (D.C.) supply on the inactivation efficiency of index microorganisms and pathogens namely Total coliforms, Faecal coliforms, *E. coli* and *Faecal streptococci* and pathogens, namely *Salmonella* spp. and *Shigella* spp. The optimum current intensity (Ampere (A)) and contact time for 80 to 95 % inactivation of pathogen indicators and pathogens were observed to be (1A 90 minutes) and (2A 90 minutes).

Key Words: Water, Disinfection, Electrolytic, Pathogen, Deactivation

INTRODUCTION

The WHO estimates that 94% of the diarrheal cases are preventable through modifications to the environment, including access to safe water [1]. Reducing the number of deaths from waterborne diseases is a major public health challenge in developing countries. It was estimated that contaminated water was responsible for around 16 million deaths per year, among which 3 million children were under the age of 5 who died due to diarrheal diseases during the year 1990 [2].

Presently, the method of water disinfection by chlorination is in vogue [3] and effective; however, with disadvantages like unfavorable taste, odor, and toxic and mutagenic byproducts including trihalomethanes [4]. Recently, electrochemical disinfection is widely applied to wastewater treatment for removal of organic pollutants in food and pharmaceutical industries. Active research is being carried out to refine this method for its application to disinfection of surface water for drinking purpose. The efficiency of this method is reported as 100% mortality of *Artenia salina* [5], removal of *Salmonella typhirmurium* bacteria using ammonium sulfate as electrolyte with stainless steel electrodes [6], removal of bacterial spores in chlorinated water [7] and inactivation of *E. coli* O157:H7 in contaminated water [8]. Several cell configurations and electrode materials have been reported for electrochemical disinfection of various microorganisms. The inactivation efficiency of microorganism depends on various factors such as cell configuration, electrode material, electrolyte composition, current intensity and type of microorganisms [9].

In the present study, the natural lake water contaminated with coliforms, *E. coli* (index organism), Faecal streptococci (index organism), *Salmonella* spp. (Pathogenic organism) and *Shigella* spp. (Pathogenic organism) *was* treated in an electrolytic disinfection unit (EDU) using aluminum electrodes without the addition of electrolytes, to evaluate its microbial deactivation efficiency from lake water. Laboratory scale experiments were carried out to study the various parameters which affect the inactivation efficiency such as current intensity, disinfection time, concentration of pathogens, etc. The study was carried out using direct current (D.C.) throughout the experiments.

MATERIALS AND METHODS

The study was carried out on the water samples collected from Futala Lake, located (21° 09' 13.46" N – 79° 02' 35.67" E) in Nagpur City, Maharashtra, India. The study was carried out during pre-monsoon (March to May) and post-monsoon (October to December) seasons of the year 2011, using engineered EDU for bacterial deactivation in lake water. The suitable microbiological growth media (Hi-Media Laboratories Pvt. Ltd, Mumbai, India) was used to isolate different microbial groups. All electrolytic disinfection experiments were carried out at a temperature range of 20°C - 23°C.

The aluminum plate electrodes placed in the 15 L capacity EDU were washed, rinsed & sterilized. Raw water sample from Futala Lake was collected in 40 L capacity polypropylene air tight barrel and brought to the laboratory. The lake water was filtered through Whatman (No.42) filter paper with the help of sterilized funnel

into the EDU to avoid solid particles. Then the DC electric current of 1A or 2A was passed through the raw test water from disinfection time of 30 minutes, 60 minutes and 90 minutes. A submersible pump was operated for continuous circulation of raw test water in EDU during the disinfection process. The 500 ml water sample, each of raw test water at zero minute and treated water samples at different durations of time, i.e. 30, 60, and 90 minutes were collected in sterilized HDPE bottles (Make-Tarson) for physicochemical and bacteriological analysis. The bacteriological analysis was performed in triplicate using Standard Membrane Filtration Technique (MFT) (9215-D) (Make: Millipore, Bangalore, India) [10, 11]. The culture media used for bacteriological analysis were EMB agar for *E. coli*, SS agar for *Salmonella* spp. *& Shigella* spp., KFSA agar for Faecal streptococci, M-Endo agar for Total coliforms and M-FC agar for Faecal coliforms. Total coliform colonies, formed after incubation for 24 h at 37°C, gave a green metallic sheen. Faecal coliforms colonies, formed after incubation for 24 h at 44.5 ^{0}C, were blue in colour. *E. coli* colonies, formed after incubation for 24 h at 37 °C, were metallic blue green in colour. Faecal streptococci colonies, formed after incubation for 24 h at 37 °C, were pink to red in colour. Colonies of *Salmonella* were black and those of *Shigella* were small and colorless. To confirm their presence, suspected colonies were further subjected to various biochemical tests that included IMViC test, TSI test and Urease test.

RESULTS AND DISCUSSION

Climatic Conditions of Nagpur

Nagpur is the second capital and third largest city of the Maharashtra, India after Mumbai and Pune. Nagpur has tropical wet and dry climate (Köppen climate classification) with dry conditions prevailing for most of the year. The average rainfall of Nagpur City is 1100 mm. Summer is extremely hot, lasting from March to June, with May being the hottest month. Winter lasts from November to January, during which temperature drops below 10 °C (50 °F). The highest recorded temperature in the city was 48 °C on May 19, 2015, while the lowest was 3.9 °C. The Hot and dry climate along with unsanitary conditions resulted in fast eutrophication of the lakes in Nagpur City with diverse pathogenic microorganisms.

Futala Lake

Futala Lake is one of the lakes in Nagpur City. The lake is spread over 60 acres. Built by Bhonsle King in Nagpur, the lake is known for its coloured fountains. In the evening, the place is illuminated with halogen lights and horse carriage rides. The lake is surrounded on three sides by forest and a landscaped Chowpatty on one side. The quality of the lake water was observed to be deteriorated due to intrusion of excessive pollutant load. The catchment area of the lake is 37.58 ha and the average depth of the lake is 4 to 5 meters. The contaminated runoff, washing activities, agricultural runoff, effluent disposal, domestic animals entering shallow banks and immersion of holy idols has caused eutrophication and silting of the lake.

Electrochemical Disinfection Unit (EDU)

The EDU consisted of plastic container of 15 liter (L) capacity with Aluminum (Al) plate electrodes immersed in the test solution. Aluminum plate electrodes were cut from a commercial grade Al sheet (99% purity) of 2 mm thickness each with a dimension of 180 mm × 100 mm and an effective area of 180 cm^2 on each side. The plates were placed 10 mm (1 cm) apart in the EDU. The mono-polar 3 electrodes connected in parallel were used in EDU for the experiments. A direct current (DC) by stabilized power supply (stabilized power supply unit number was TESTRONIX 34C, 1 - 15V (Volt), 0 - 5 A (Ampere) with Digital Display) was applied to the terminal electrodes in which electrical current was controlled by a variable transformer. The circulation of water in the EDU was maintained by submersible water pump to ensure complete mixing of the raw test water. Before each experiment, the electrodes were abraded with sandpaper to remove scale and then cleaned with successive rinsing of water and 1N H_2SO_4 and was sterilized. The electric current was monitored over the course of each experiment.

Quality of Futala Lake Water

The physicochemical quality of Futala lake water is shown in Table I. The pH ranged from 7.04 to 8.00 in pre monsoon season and 8.11 to 8.34 in the post monsoon season indicating alkaline lake due to eutrophication and development of primary producers like algae and weeds in the lake. The turbidity ranged from 2.3 to 3.5 NTU in pre monsoon and 4.9 to 5.7 NTU in the post monsoon season, showing higher turbidity as compared to drinking water standard of 1 NTU. The total dissolved solids (TDS) were observed to be in the range of 184-210 mg/l in pre monsoon and 274-307 mg/l in the post monsoon season, being below the drinking water standard of 500 mg/l. However, the BOD ranging from 5 to 7 mg/l and COD from 5 to 16 mg/l showed organic pollution of lake water. The BOD/COD ratio ranged from 1.042 to 2.29, the values above 0.5 indicate easily biodegradable organic matter which is coming from domestic wastewater. Nutrient enrichment was shown by the nitrate and phosphate content in the lake water ranging from 0.26 to 0.6 mg/l and 0.03 to 0.21 mg/l respectively. Lake water

with phosphate more than 0.05 mg/l and nitrates more than 0.5 mg/l are considered as eutrophic and polluted [12]. Mesotrophic nature of Futala Lake is reported [13]. Excessive nutrient load in Futala Lake has caused the heavy growth of water hyacinth, water lily, hydria, wolfia, potamogeton and algae. Futala Lake with W.Q.I. ranging from 55.81 to 169.37 falls under the poor water category and the trophic status of Futala Lake as per the above classification varies from mesotrophic to hyper eutrophic during different months [14]. Heavy metal pollution of Futala Lake has been reported with higher concentration of Fe, Pb, Zn, Cr above the ranges of unpolluted lake [15]. Futala Lake was observed to be mesotrophic in 1996 and eutropic in 2010 [16]. They also reported the presence of organic pollution indicator algal species like *Euglena acus, Microcystis aeruginosa, Oscillatoria limnetica, Raphidiopsis curjanta, Ankistrodesmus falcatus, Chlorella vulgaris, Navicula schizanema* and *Nitzchia bilobata* and zooplankton species like *Brachionus* sp., *Keratella* sp., *Lecane* sp. and *Asplanchna* sp in the lake water.

Microbiological quality of Futala Lake raw water is presented in Table II. Total coliforms, faecal coliforms, *E. coli* and *Faecal streptococci* or intestinal Enterococci are index organisms while *Salmonella* spp. and *Shigella* spp. are pathogenic organisms responsible for gastroenteritis and bacillary dysentery respectively. There is a strong positive correlation of all indicators with *Salmonella* and moderate positive correlations with *Staphylococcus aureus* and *Candida albicans* in sewage polluted sea water; Total coliforms correlated well with *Salmonella* spp. and *Staphylococcus aureus* than did the two other fecal groups. Thus, the enumeration of Total coliforms is sufficient to predict the presence of *Salmonella* spp. or *Staphylococcus aureus* in moderately polluted water [17].

In Futala Lake raw water, total coliforms (CFU/100 ml) ranged from 850 to 873 in pre monsoon season and 1143 to 1150 in post monsoon season (Table 2). As per CPCB classification of surface water quality, the value of total coliforms between 500 to 5000 CFU/100 ml, indicate polluted surface water that belongs to Class C of surface water which is considered as a raw water source with conventional treatment followed by disinfection. Total coliforms are considered as a probable indicator of contamination and do not imply an imminent health risk but does indicate the need for an analysis of all water system facilities and their operations to determine the source of contamination.

Faecal coliforms ranged from 350-433 CFU/100 ml in pre monsoon and 593-623 CFU/100 ml and *E. coli* ranged from 127-153 CFU/100 ml in pre monsoon and 207-210 CFU/100 ml in post monsoon. Faecal coliforms, a subset of Total coliforms, are more useful as indicators in recreational waters than Total coliforms which include species that are naturally found in plants and soil. *E. coli* appears to be the best indicator of bacteriological quality of water, primarily because of the availability of affordable, fast, sensitive, specific and easier to perform detection methods for *E. coli*. However, the life span of *E. coli* in water is short, thus it best determines recent contaminations. It is therefore important to continuously monitor the *E. coli* to determine the bacteriological quality of water [18]. As per the drinking water quality standard (IS 10500: 2012), *E. coli* is more precise indicator of Faecal pollution even though the count of thermotolerant coliform bacteria is an acceptable alternative. However, one species enterohaemorrhagic *Escherichia coli* is pathogenic. As per drinking water quality standard, their presence shall not be detectable in any 100 ml sample in all water intended for drinking. However, as per the standard for packaged drinking water offered for sale in packaged form (IS 14543:2004) and standards for natural mineral water offered for sale in packaged form for human consumption (IS 13428:2005), the *E. coli* or thermotolerant bacteria, coliform bacteria, Faecal streptococci, *Staphylococcus aureus*, *Salmonella* spp. and *Shigella* spp. shall be absent in 250 ml water sample.

Above observations on lake water are well supported by the presence of Faecal streptococci in lake water. Its count varied from 87-90 CFU/100 ml in pre monsoon and 120-137 CFU/100 ml in post monsoon. Faecal streptococci is used as index of faecal pollution in water bodies, however, the group includes species of different sanitary significance and survival characteristics [19, 20]. In addition, streptococci species prevalence differs between animal and human faeces [21, 22].

The pathogenic organisms *Salmonella* spp. and *Shigella* spp. are present in considerable number in the raw lake water. *Salmonella* spp. ranged from 117-143 CFU/100 ml in pre monsoon and 143-187 CFU/100 ml in post monsoon; and *Shigella* spp. ranged from 73-87 CFU/100 ml in pre monsoon and 107-110 CFU/100 ml in post monsoon season. *Salmonella* and *Shigella* are different groups of Gram-negative bacteria. *Salmonella* are a group of bacteria that can be divided into typhoid *Salmonella* (*Salmonella typhi*) which causes typhoid fever and non-typhoid *Salmonella*. The latter is commonly known for causing salmenollosis which is a type of food borne intestinal infection contracted after eating food contaminated with the *Salmonella* bacteria. These types of intestinal infections are more likely in children or the elderly. *Shigella* is a family of bacteria that cause an infectious intestinal disease known as shigellosis. It is mainly transmitted through contact with an infected person and contaminated food and water. Shigellosis can occur in any age group but is more commonly seen in children. It is one of the common causes of outbreaks of bacillary dysentery. *Salmonella* infection requires a larger infective dose than for *Shigella* infection. This means that more bacterial cells need to be ingested for salmonellosis than for shigellosis. The symptoms of both diseases resolve within 7 days or less in most people. Deaths from both diseases are uncommon but are more likely to occur in children with shigellosis. In general,

the microbial concentration was found to be more in post monsoon season. This might be due to more input of pollutants in the lake along with runoff water in the preceding rainy season.

The World Health Organization (WHO) recommends that treated wastewater for unrestricted irrigation should contain less than 1,000/100 ml Faecal coliforms. The Faecal coliforms in Futala Lake water ranged from 350 to 623 CFU/100 ml, and thus lake water is suitable for unrestricted irrigation. The above observations showed that the Futala Lake is polluted with the presence of index species and pathogenic organisms. As per the guidelines for evaluation of quality of irrigation water, the EC of Futala Lake water, i.e. 296 to 512 µS/cm indicate low hazard (below 1500 µS/cm) to crops. The guideline upper limit of dissolved solids for irrigation is 2100 mg/l (IS: 2490, Part-I-1981). The total dissolved solids in Futala Lake water is 184-307 mg/l which is good for the crops. In conclusion the Futala Lake is suitable as irrigation water, but not as drinking water source.

Quality of Treated Water and Inactivation Efficiency of EDU

Preliminary experiments were carried to select the current intensity and disinfection time. Based on the results, disinfection time of 30 min, 60 min and 90 min and current intensity of 1 Ampere (A) and 2 Ampere (A) were selected for the study. The results on the physicochemical quality of treated water are shown in Table III. The pH of water was reduced to 7.51 to 7.79 except 1A post-monsoon treatment. There was a prominent reduction in conductivity, TDS and turbidity especially in post monsoon season samples in 2A treatment. There is also reduction in the concentration of nitrate-N and phosphate-P. This might be due to destruction and removal of microbial turbidity in the water.

Residual microbial counts in the pre-monsoon treated lake water samples are shown in Table IV and percentage inactivation as compared to untreated lake water are shown in Table IV and Figure 1. Maximum inactivation in all microorganism groups was observed in case of treatment (2A 90 min) ranging from 91% to 100% inactivation, the maximum being in Faecal streptococci; *Salmonella* spp. and *Shigella* spp. also inactivated considerably. This was closely followed by the treatment (1A 90 min), with 76% to 86% inactivation in all microorganism groups, with highest inactivation (85% to 86%) in *Salmonella* spp. and *Shigella* spp. The treatment (2A 60 min) showed higher fluctuations in inactivation ranging from 60% to 82%, followed by treatment (1A 60 min) with 44% to 77% inactivation; treatment (2A 30 min) with 32% to 69% inactivation and treatment (1A 30 min) with 12% to 37% inactivation in all microorganism groups. Based on average of inactivation of all microorganism groups, the efficiency of the treatment process is given in Table VI.

Residual microbial counts in the post-monsoon treated lake water samples are shown in Table V and percentage inactivation as compared to untreated lake water are shown in Figure 2. Maximum inactivation in all microorganism groups was observed in case of treatment (2A 90 min) ranging from 91 to 98 percent, maximum being in *Salmonella* spp. This was closely followed by the treatment (1A 90 min), with 79% to 91% inactivation in all microorganism groups, with highest inactivation (91%) in *Salmonella* spp. The treatment (2A 60 min) also showed higher fluctuations in inactivation ranging from 66% to 80%, followed by treatment (1A 60 min) with 48% to 66% inactivation; treatment (2A 30 min) with 31% to 47% inactivation and treatment (1A 30 min) with 37% to 48% inactivation in all microorganism groups. Based on average of inactivation of all microorganism groups, the efficiency of the treatment process is given in Table VI.

It is evident from Table VI that inactivation in all microbial groups above 80% is achieved by two treatments, namely (2A 90 min) and (1A 90 min) with approximately 95% and 85% inactivation; and 50% to 75% inactivation is achieved by treatments (2A 60 min) and (1A 60 min). Remaining treatments showed less than 50% inactivation and are not efficient and feasible from practical point of view. It is also evident from Table V that the pathogenic microorganism *Salmonella* spp. can be inactivated at (2A 90 min) and (2A 60 min) by 80% to 95% respectively, and at (1A 90 m) by 91%. The pathogen *Shigella* spp. is observed to be more resistant and can be effectively inactivated only at (2A 90 min) treatment by 91%.

Log Liner Kinetic Model for Microorganism Inactivation

The principle law of disinfection kinetics is given by H. Chick. Here the modified kinetic model for evaluation of the process of electrolysis is designed for the disinfection of natural water contaminated with coliforms and pathogens [3, 6]. According to this model, the initial number of pathogenic microorganisms (N_0) and the electrolytically treated (deactivated) number of pathogenic microorganisms (N) at a time (moment) t are interrelated as follows:

$\text{Log } N = \log N_0 - kt$ (1)

Where, k is the factor depending on the current intensity for a constant volume of water to be disinfected and constant surface area of the electrodes.

The results obtained from the log linear model are preseneted in Figure 3. The values of the correlation coefficient between the number of inactivated pathogens and time of treatment varied between 0.868 to 0.975, being good fit to the linear model. The slope of the straight line represents the first order kinetic coefficient [5]. These values are observed in the range between -0.0064 and -0.0099 (Table VII). Thus, the number of

inactivated pathogens in the treated water (N) was dependent on treatment time (t); there is a linear relation between N and t.

Conclusion

Water is a natural resource and is essential to sustain life. Accessibility and availability of fresh clean water does not only play a crucial role in economic development and social welfare, but also it is an essential element in health, food production and poverty reduction [23]. However, safe drinking water remains inaccessible for about 1.1 billion people in the world and the hourly toll from biological contamination of drinking water is 400 deaths of children below the age five [24]. The conventional water disinfection methods have many disadvantages of releasing toxic byproducts and taste and odour problem. The present work confirms the efficacy of electrolytic disinfection at aluminium electrodes for the microbial inactivation of surface water. In view of this, electrolytic method is highly efficient to inactivate the pathogens apart from its cost-effectiveness and easy technology to get safe domestic and drinking water.

Acknowledgement

The authors are thankful to the Principal, Sevadal Mahaila Mahavidyalaya and Research Academy, Nagpur, India for constant encouragement and for providing facilities to conduct the present investigation. Authors are also highly thankful to Dr. Pawan Labhasetwar and Mr. S. P. Andey, Scientists, CSIR-NEERI, Nagpur for their guidance from time to time during this research project.

References

[1]. WHO, *Combating Waterborne Diseases at the Household Level*, World Health Organization, 2007. Part 1. ISBN 9789241595223.

[2]. J. Diamond, The return of cholera, *Discover*, 1992, 60-66.

[3]. G. Patermarkis and E. Fountoukidis, Disinfection of water by electrochemical treatment, *Water Research, 24(12)*, 1990, 1491-1496.

[4]. C.A. Martines-Huitle and E. Brillas. Electrochemical Alternatives for drinking water disinfection, *Angew. Chem. Int. Ed, 47*, 2008, 2-10.

[5]. Efi Tsolaki, Pitta Paraskevi, Evan Diamadopoulos, Electrochemical disinfection of simulated ballast water using *Artemia salina* as indicator, *Chemical Engineering Journal, 156*, 2010, 305-312.

[6]. N.N. Barashkov, D. Eisenberg, G. Sh. Shegebaeva, I. S. Irgibaeva and I.I. Barashkov, Electrochemical chlorine-free AC disinfection of water contaminated with *Salmonella typhirium* Bacteria, *Russian Journal of Electrochemistry, 46(3),* 2010, 306-311.

[7]. L. Mezule, M. Reinmanis, V, Krumplevska, J. Ozolins and T. Juhna, Comparing electrochemical disinfection of bacterial spores in drinking water, *Water Science & Technology: Water Supply*, 2014, 14.1.

[8]. F. Lopez-Galvez, G.D. Posada-Izquierdo, M.V. Selma, F. Perez-Rodriguez, J. Gobet, M.I. Gil, A. Allende, Electrochemical disinfection: An efficient treatment to inactivate *Escherichia coli* O157:H7 in posh wash water containing organic matter, *Food Microbiology, 30*, 2012, 146-156.

[9]. M.I. Kerwick, S.M. Reddy, A.H.L. Chamberlain, D.M. Holt, Electrochemical disinfection. An environmentally acceptable method of drinking water disinfection? *Electrochemica Acta (50),* 2005, 5270-5277.

[10]. NEERI, *Guidance Manual for Drinking Water Quality Monitoring and Assessment,* National Environmental Engineering Research Institute, Nagpur, 2010.

[11]. Public Health Association (APHA), Standard *Methods for the Examination of Water and Wastewater* (21st Ed.), (eds) Clescerl, Leonore S., Greenberg, Arnold E., Eaton, Andrew D., American Public Health Association (APHA), Washington D.C., 2005, ISBN 0-87553-235-7.

[12]. P.F. Toner, *Eutrophication*, Water Resources Division, 1977, A Foras Forbartha.

[13]. Kirti Y. Lanjewar, and Prakash S. Kelkar, Studies on rejuvenation of Futala Lake, Nagpur. In: Sengupta M. and Dalwani R. (Editors), 2008, *Proceedings of Taal 2007: The 12th World Lake Conference*: 1660-1668.

[14]. P.J. Puri, M.K.N. Yenkie, D.B. Rana, S.U. Meshram and L.S. Awale, Surface water (Futala Lake) quality and its pollution load in terms of water quality index (WQI). *Advances in Applied Science Research, 6(1),* 2015, 15-26.

[15]. P.J. Puri, M.K.N. Yenkie, S.P. Sangal, N.V. Gandhare and G.B.Sarote, Study regarding lake water pollution with heavy metals in Nagpur City (India). *International Journal of Chemical, Environmental and Pharmaceutical Research (IJCEPR), 2(1)*, 2011, 34-39.

[16]. Sanyogita R. Verma, P.R. Chaudhari, and S.R. Wate, Studies on the ecology and trophic status of an urban lake at Nagpur City, India. *Rasayan J. Chem., 4(3),* 2011, 652-659.

[17]. M.A. Efstratiou, A. Mavridou, S.C. Richardson, J.A. Papadakis, Correlation of bacterial indicator organisms with *Salmonella* spp., *Staphylococcus aureus* and *Candida albicans* in sea water. *Lett Appl Microbiol, 26(5)*, 1998 May, 342-6.

[18]. S.T. Odonkor and J.K. Ampofo, *Escherichia coli* as an indicator of bacteriological quality of water: an overview. *Microbiological Research, 4:e2*, 2013, 5-11

[19]. V. Gauci, Enumeration of faecal streptococci in seawater. In: *Development and Testing of Sampling and Analytical Techniques for Monitoring of Marine Pollutants (Activity A): Final Reports on Selected Microbiological Projects.* Athens, United Nations Environment Programm,, 1991, pp. 47–59 (MAP Technical Reports Series No. 54).

[20]. L.W. Sinton, A.M. Donnison, Characterization of faecal streptococci from some New Zealand effluents and receiving waters, *New Zealand Journal of Marine and Freshwater Research, 28*, 1994, 145–158.

[21]. A.A. Rutkowski, R.E. Sjogren, Streptococcal population profiles as indicators of water quality. *Water, Air and Soil Pollution, 34*, 1987, 273–284.

[22]. A.M. Poucher, L.A. Devriese, J.F. Hernandez, J.M. Delattre, Enumeration by a miniaturized method of *Escherichia coli*, *Streptococcus bovis* and enterococci as indicators of the origin of faecal pollution of waters, *Journal of Applied Bacteriology, 70*, 1991, 525–530.

[23]. N.J. Ashbolt, W.O. Grabow, M. Snozzi, Indicators of microbial water quality. In: Fewtrell F, Bartram J. (eds.), *Water Quality - Guidelines, Standards and Health Assessment of Risk and Risk Management for Water-Related Infectious Disease*. Geneva: World Health Organization; 2001, pp. 256-276.

[24]. A. Gadgil, Drinking water in developing countries. *Annu Rev Energy Environ, 23*, 1998, 253-86.

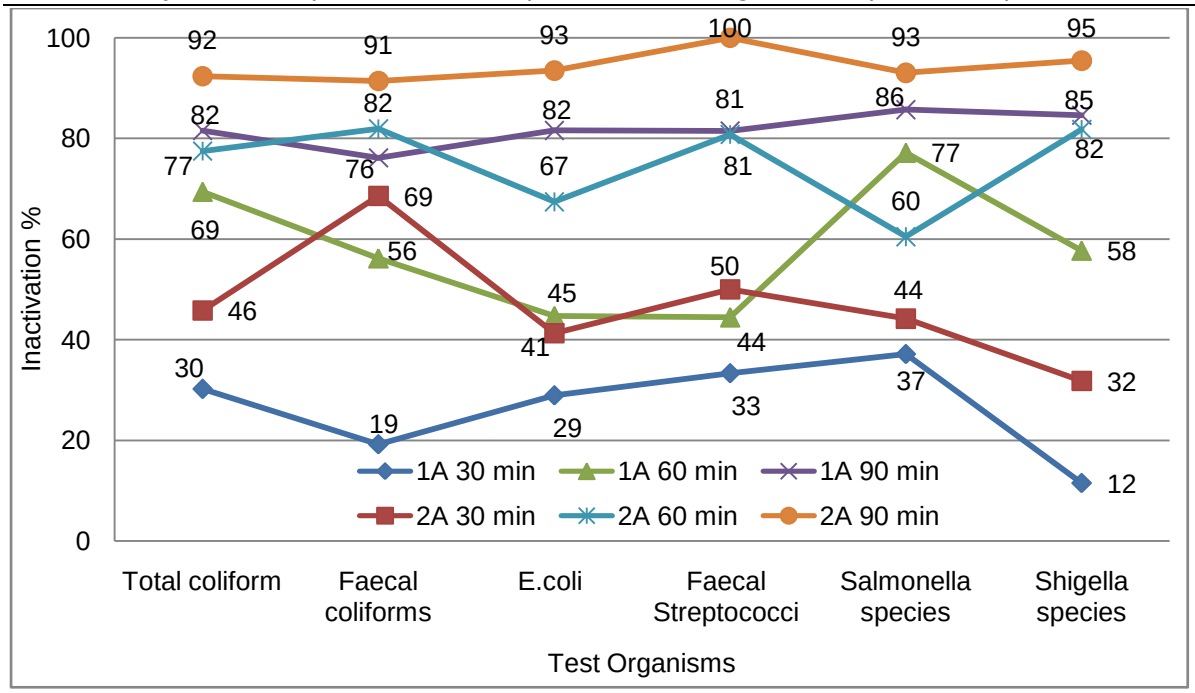


Figure 1: Percentage Deactivations of Microorganisms in All Microbial Groups in Each Treatment in Pre Monsoon 2011 at 1A & 2A

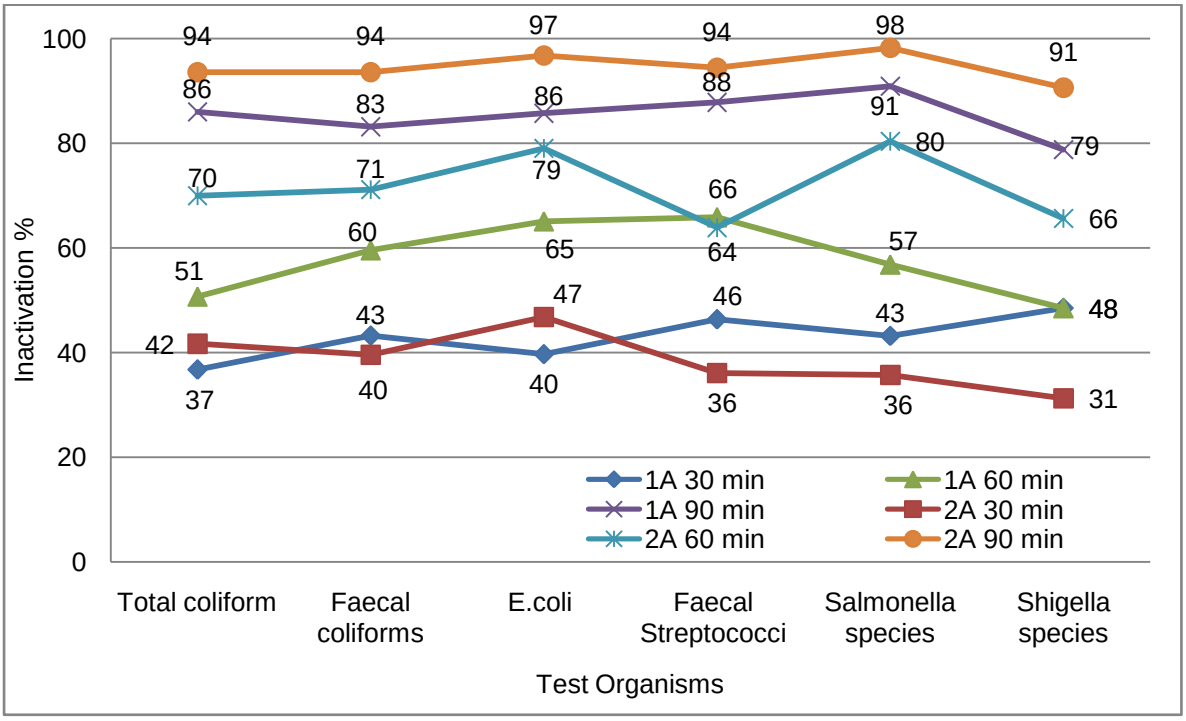
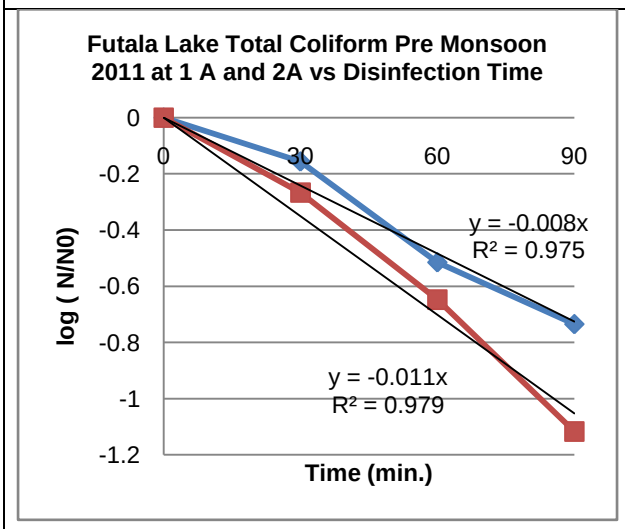
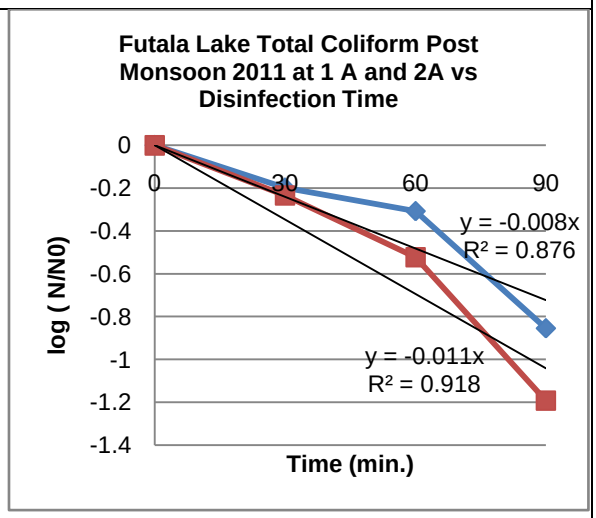
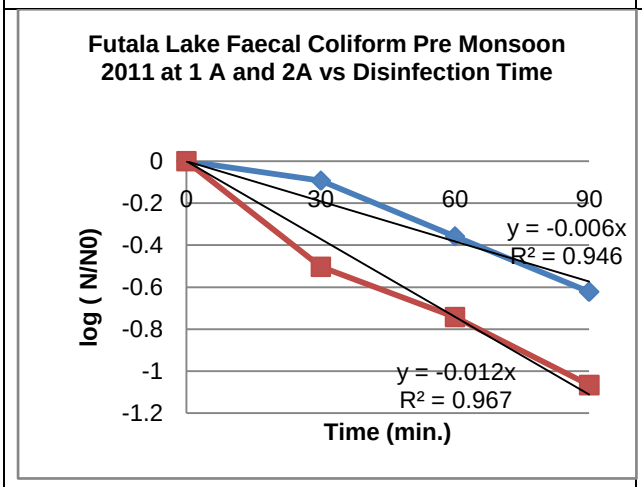
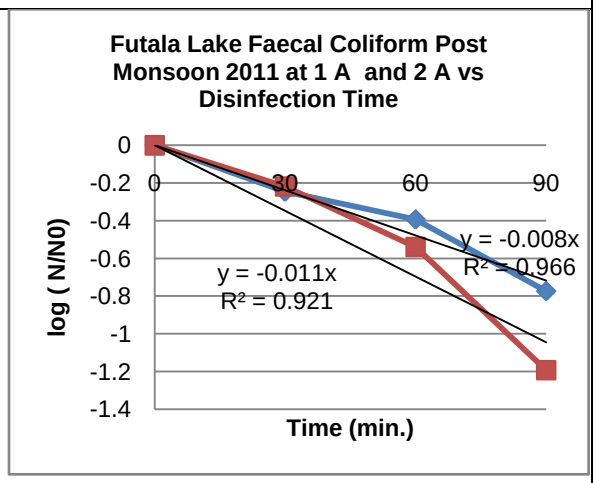
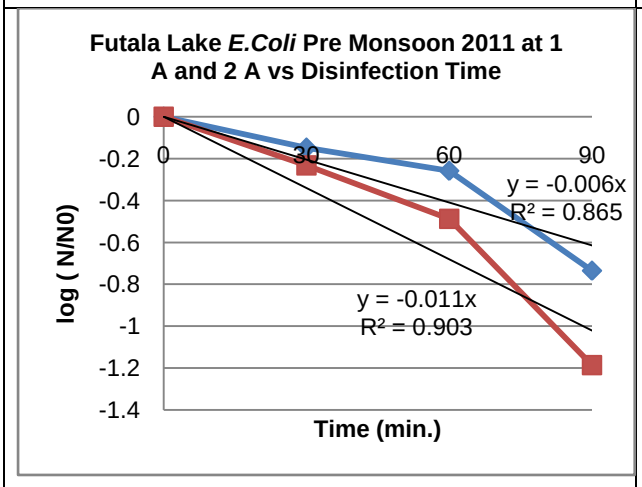
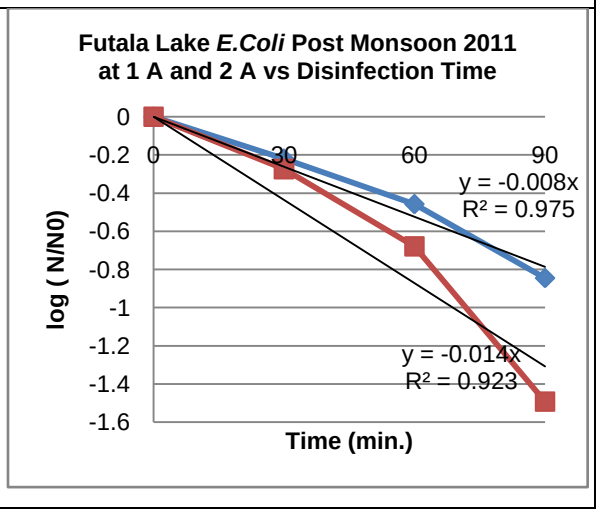


Figure 2: Percentage Deactivations of Microorganisms in All Microbial Groups in Each Treatment in Post Monsoon 2011 at 1A & 2A

Pre Monsoon 2011 at 1A and 2A	Post Monsoon 2011 at 1A and 2A
	
	
	

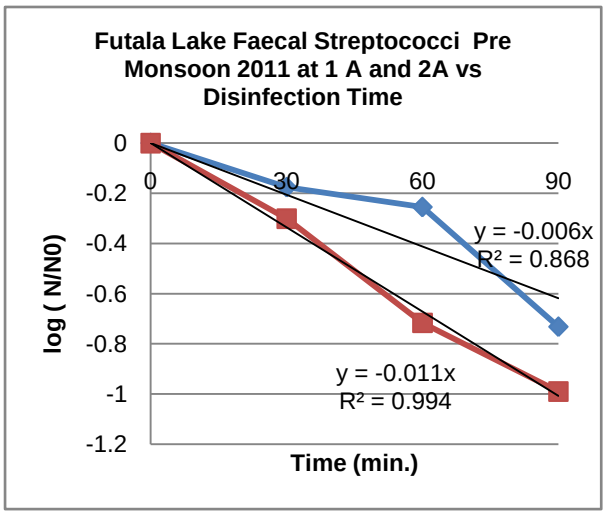
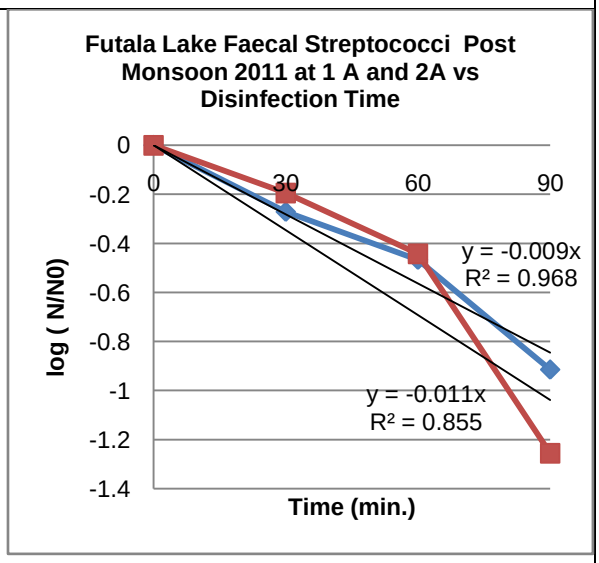
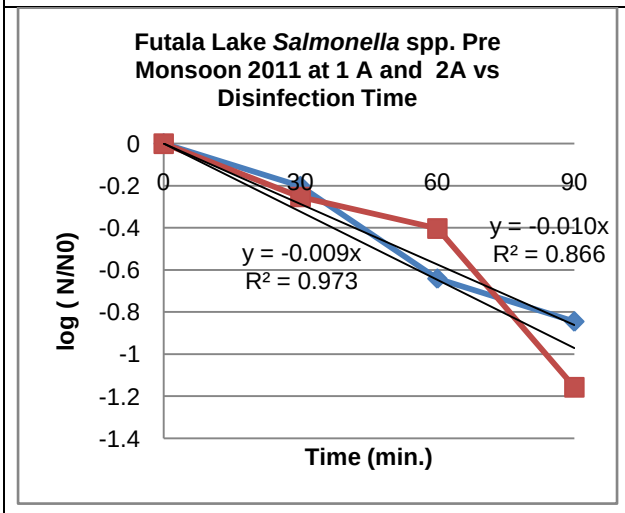
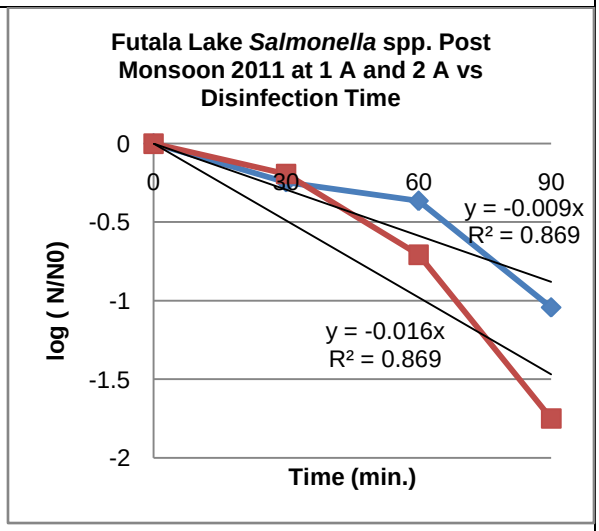
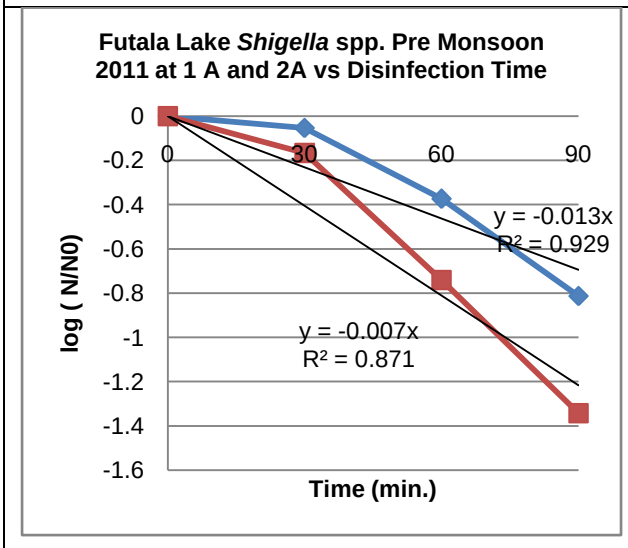
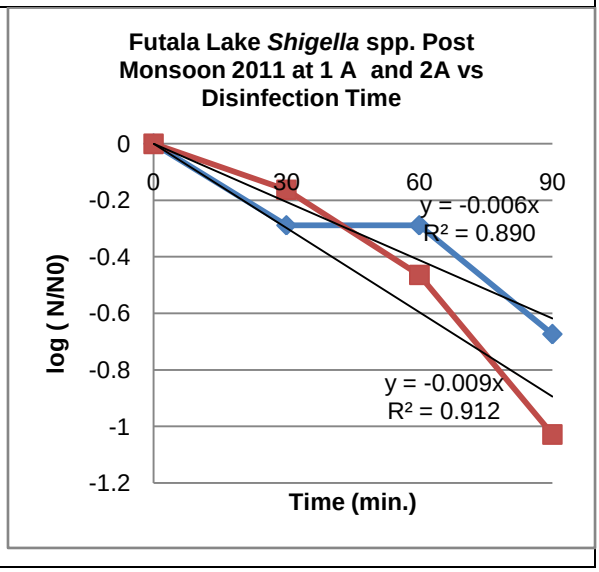
Pre Monsoon 2011 at 1A and 2A	Post Monsoon 2011 at 1A and 2A
	
	
	

Figure 3: Linear Log Model for Pre and Post Monsoon 2011 at 1A & 2A

Table I: Physicochemical Quality of Raw Futala Lake Water

	pH	Temp. (ºC)	Conductivity (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Nitrate-N (mg/L)	Phosphate-P (mg/L)
Pre Monsoon 2011	7.04 -8.00	22.1 - 22.9	296 - 350	184 -210	2.3 - 3.5	0.5-0.6	0.18-0.21
Post Monsoon 2011	8.11 – 8.34	20.2 - 22.0	457 - 512	274 - 307	4.9 – 5.7	0.26-0.35	0.03-0.15

Table II: Microbiological Quality of Raw Futala Lake Water

	Total Coliforms (CFU/100ml)	Faecal Coliforms (CFU/100ml)	*E. coli* (CFU/100ml)	Faecal Streptococci (CFU/100ml)	*Salmonella* species (CFU/100ml)	*Shigella* species (CFU/100ml)
Pre Monsoon 2011	850 - 873	350 - 433	127 - 153	87 - 90	117 - 143	73 - 87
Post Monsoon 2011	1143 - 1150	593 - 623	207 - 210	120 - 137	143 - 187	107 - 110

*Note: mean of triplicate batch

Table III: Physicochemical Quality of ElectrolyticallyTreated Futala Lake Water

	Current Intensity	pH	Temp. (ºC)	Conductivity (µS/cm)	TDS (mg/l)	Turbidity (NTU)	Nitrate-N (mg/L)	Phosphate-P (mg/L)
Pre Monsoon 2011	1A	7.51	20.8	345	206	4.9		
	2 A	7.61	22.1	313	188	4.3	0.3-0.4	0.15-0.18
Post Monsoon 2011	1A	8.94	27.5	391	235	2.7		
	2 A	7.79	24.1	387	232	2.5	0.20-0.28	0.02-0.12

Table IV: Microbial Quality of Electrolytically Treated Futala Lake Water (Pre-Monsoon) and Pecentage Deactivation of Microorganisms

	Time (in min.)	Total Coliforms (CFU/100ml)	Inactivation %	Faecal Coliforms (CFU/100ml)	Inactivation %	*E. coli* (CFU/100ml)	Inactivation %	Faecal Streptococci (CFU/100ml)	Inactivation %	*Salmonella* species (CFU/100ml)	Inactivation %	*Shigella* species (CFU/100ml)	Inactivation %
Pre Monsoon 2011 at 1 A	0	850		433		127		90		117		87	
	30	593	30	350	19	90	29	60	33	73	37	77	12
	60	260	69	190	56	70	45	50	44	27	77	37	58
	90	157	82	103	76	23	82	17	81	17	86	13	85
Pre Monsoon 2011 at 2A	0	873		350		153		87		143		73	
	30	473	46	110	69	90	41	43	50	80	44	50	32
	60	197	77	63	82	50	67	17	81	57	60	13	82
	90	67	92	30	91	10	93	0	100	10	93	3	95

Table V: Microbial Quality of Electrolytically Treated Futala Lake Water (Post-monsoon) and Percentage Deactivation of Microorganisms

	Time (in min.)	Total Coliforms (CFU/100ml)	Inactivation %	Faecal Coliforms (CFU/100ml)	Inactivation %	*E. coli* (CFU/100ml)	Inactivation %	Faecal Streptococci (CFU/100ml)	Inactivation %	*Salmonella* spp. (CFU/100ml)	Inactivation %	*Shigella* spp. (CFU/100ml)	Inactivation %
Post Monsoon 2011 at 1 A	0	1143		593		210		137		147		110	
	30	723	37	337	43	127	40	73	46	83	43	57	48
	60	563	51	240	60	73	65	47	66	63	57	57	48
	90	160	86	100	83	30	86	17	88	13	91	23	79
Post Monsoon 2011 at 2A	0	1143		623		207		120		187		107	
	30	667	42	377	40	110	47	77	36	120	36	73	31
	60	343	70	180	71	43	79	43	64	37	80	37	66
	90	73	94	40	94	7	97	7	94	3	98	10	91

Table VI: Average of Percentage Deactivations of Microorganisms in All Microbial Groups in Each Treatment

Treatments	Pre-monsoon (% Inactivation)	Post-monsoon (% Inactivation)	Average (% Inactivation)
2A 90 m	94	94.7	94.35
1A 90m	82	85.5	83.75
2A 60m	74.8	71.7	73.25
1A 60 m	58.2	57.5	57.85
2A 30m	47.7	38.7	43.2
1A 30m	26.7	42.8	34.75

Table VII: First Order Kinetic Coefficand between Number of Inactivated Microorganisms and Time of Treatment

Sr. No.	**Pathogen**	**K (First Order Kinetic Coefficient)**			
		Pre monsoon 2011 at 1A	**Pre monsoon 2011 at 2A**	**Post monsoon 2011 at 1A**	**Post monsoon 2011 at 2A**
1.	Total Coliform	- 0.0081	- 0.0117	- 0.008	- 0.0116
2.	Faecal Coliform	- 0.0068	- 0.0113	- 0.0087	- 0.0145
3.	*E.Coli*	- 0.0069	- 0.0112	- 0.0094	- 0.0115
4.	Faecal Strptococci	- 0.0064	- 0.0124	- 0.008	- 0.0116
5.	*Salmonella spp.*	- 0.0108	- 0.0096	- 0.0098	- 0.0163
6.	*Shigella spp.*	- 0.0135	- 0.0077	- 0.0069	- 0.0099