

Short Communication

Bactericidal Effect of Electromagnetic Field on Water

M Alam Morshed*^{1,2}, Rubaiyath Rahman¹, Nirupam Biswas¹, Sajedur Rahman¹ and Tipu Sultan¹

¹Dept. of Biotechnology and Genetic Engineering, Islamic University, Kushtia-7003, Bangladesh, ² Dept. of Pharmacy, North South University, Bashundhara, Dhaka-1229, Bangladesh.

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Contaminated water containing pathogenic microorganisms is harmful to human health. Various techniques have been used to make water free of microorganisms. An attempt was made to treat microbial contamination of the surface water with electromagnetic field. In this study, tap water was collected from the faculty of Applied Science & Technology and lake water from the Mofiz lake at Islamic University, Kushtia, Bangladesh. The electromagnetic field was generated by small coils of wire hooked to a 220 V current source on the viable heterotrophic bacteria in tap and lake water. Water samples were placed in glass vials around which wire was wrapped, and connected to a 50Hz house current. Water samples were exposed to electric fields produced by several different coils with varying numbers of turns for varying lengths of time. In another experimental design, water was pumped through a pipe around which wire was wrapped to create an electric field, and in both of the cases, water free of the microbes was obtained. Microbial contamination was measured by colony count on nutrient agar media. Thus, this technique can be used for purifying water contaminated with harmful microorganisms.

Key words: Bactericidal, microorganism, electromagnetic field, surface water.

Water is essential for the survival of all forms of lives. Safe drinking water is a basic human right essential to all. Our society relies heavily on clean, potable water (drinking water). Though water is necessary for human survival, many people of our country have limited or no access to sufficient potable drinking water supply and sufficient water to maintain basic hygiene. Water sources such as lakes, rivers and ground water may contain chemicals, both naturally occurring and manmade, and other organisms that degrade its aesthetic quality and palatability. Furthermore, the chemicals and organisms contained in these waters may be harmful to human health. One of the major chemical problems in water is arsenic causing people to suffer in our country. Moreover, there are very few techniques available to us to remove the arsenic from contaminated water. This type of problem is found in case of ground water, but surface water is generally free from arsenic. For this reason, the Government has recommended the use of surface water for drinking and other purposes to avoid arsenic. More problems are created when the surface water is rich in microbial contamination from various sources. As a result, water that is used as a source of drinking water must be carefully managed and treated to remove harmful chemicals and microorganisms. Globally, 1.1 billion people rely on unsafe drinking water sources from lakes, rivers, and open wells. The majority of these are in Asia (20%) and sub-Saharan Africa (42%). Furthermore, 2.4 billion people lack adequate sanitation worldwide¹⁻². Safe drinking water supply is therefore a matter of concern.

Microbial contamination of water is a major cause of health and economic problems. Progress is being made in the techniques used to identify the pollutants, but the costs are questionable, and must be avoided to prevent future crisis. For all the reasons mentioned above, an effective technology of reasonable cost aimed at water purification must be developed.

In Bangladesh, electrical devices used to produce low-frequency electromagnetic field (EMF), specially at residents living near electrical transformers or high voltage distribution where lines are affected. EMF, supplied by electricity systems, is of low frequency (50 Hz) and can be effective at different intensities depending on the distance to the system and the power of system³. It is known that biological systems produce different biological responses to applications of EMF at different frequencies and intensities⁴. Various living organisms are differently affected from EMF, and these effects vary according to the regions applied and at the level of the cell⁵⁻⁷.

An electrically charged particle exposed to an electromagnetic field will experience a force on it. If the particle is at rest, this force will be due to the electric field. Otherwise, both electric and magnetic forces will be present. All the electrically charged particles in living tissues will experience forces when exposed to electric and/or magnetic fields. Because living tissues are conductors, these forces will cause electric currents to flow⁸⁻¹⁰.

Electric fields are produced by electric charges; a magnetic field is also produced if these charges are in motion. Electric fields

***Corresponding author**

Md. Morshed Alam, Research Officer, Pharmacology and Pharmaceutical Microbiology Lab, Dept. of Pharmacy, North South University, Bashundhara, Dhaka-1229, Bangladesh. Tel: +88-01712814302, Fax: +88-2-8852016, Email: morshedbt@gmail.com

exert forces on other charges; if in motion, these charges will experience magnetic forces. Power-frequency electric and magnetic fields induce electric currents in conducting bodies, such as living organisms. Magnetic Field (MF) and Electromagnetic Field (EMF), which have started to draw an increasing attention by the researchers, are related to each other. Researchers working in scientific fields of biology, medicine, and agriculture have been interested about the influences of MF and EMF exchanges on the biological structures and much work has been carried out on this topic. Based on past studies, it was determined that there were no significant differences between MF and EMF's effect of mechanisms of the biological systems¹¹. In numerous experiments, it has been investigated that EMF's effects on organisms vary depending on the intensity of the magnetic field, frequency, exposure duration to EMF, genotype of organisms and the biological system¹²⁻¹⁵. Keeping these in mind, a new technology was proposed in this study for the first time that can be used for treatment of water to make it free from microorganisms, using low-cost electromagnetic field.

Water samples were collected from the tap of the Faculty of Science at Islamic University, and from the Mofiz Lake of Islamic University, Kushtia, Bangladesh. For collection of samples, beakers were washed and autoclaved at 121°C for 25 minutes at 15 lb/inch², and maintained under aseptic conditions. Nutrient agar medium (High media, New Delhi, India) was used for bacterial growth, and other apparatuses including bulbs (200w), insulated wire, screw-capped tubes, sterilized plastic saline pipe and some electric wires were also used.

For bacterial growth, 28g of nutrient agar medium was used and was poured into autoclaved Petri dishes.

Solenoid was made by coiling the insulated wire around the sterilized screw-capped tube and the plastic saline pipe containing the sample water. The number of turn of the coil around the tube was changed according to the experimental design.

The experiment is divided into two parts. In 'Stationary tube method', lake (pond) water sample was treated by a solenoid containing screw-capped tube. In 'Pumped-flow tube method', both tap water and lake water was treated in a solenoid using plastic saline pipe.

During the investigation involving the 'Stationary tube', the collected water samples were filled into the screw-capped tubes which were in solenoid form. Both the ends of the insulated wire were connected with two electric circuits provided by a transformer (PQ26, Henzhen Jing Ye Magnetism Electronic Co., Ltd, China) having a 200w electric bulb that was connected in a series. After completion of the electric circuit, electric power was supplied by maintaining various time schedules.

In case of the 'Pumped-flow tube' experiment, 1L of the collected water sample was loaded in a sterilized bottle. The pipe in solenoid form was then attached to the bottom end of the bottle. A regulator was used to control the flow of water throughout the

pipe and the flow rate was 0.5ml/min. A 200w bulb was also connected in a series to complete the circuit. Then the regulator was turned on to allow the sample water to go through the solenoid that produced electromagnetic field (EMF) inside the pipe. EMF treated samples were collected in sterilized tube. Both EMF treated and untreated (control sample) water samples were cultured on nutrient agar medium.

The collected samples from pond and tap water (for the control - no exposure to EMF) and the water samples exposed to electromagnetic field were directly used as inoculums. One hundred microliters of each water sample was then inoculated onto nutrient agar medium by spread plate technique and incubated overnight at 37°C.

In this case, the sample water was treated for 20 minutes (35 turns of weir) and relatively small numbers of colonies were found for pond water treated with electromagnetic field compared to the control pond water.

Data from this experiment were recorded (see table-1) which demonstrated that the EMF effectively reduced the microbial growth. Results from this experiment are shown in the table-1, which also followed the effect similar to experiment (2).

From the stationary tube experiments, it was found that after a short time (about 20-40 minutes), the range of bacterial colony number varied between 9-15 cfu/100il. When the treatment time gradually increased (60-80 min), a drastic change of the bacterial colonies was observed which showed the number of bacterial colonies ranging from 2-7 cfu/100il, and even zero. This means that following the treatment of polluted water for a certain amount of time, a large number of bacterial species (the normal flora of water) that makes water unfit to drink, were adversely affected due to electromagnetic field effect.

Data from tap water samples were recorded (see table 2), which further demonstrated that the EMF specifically reduced the microbial colony. On the other hand, the EMF untreated (control) sample displayed uncountable numbers of bacterial colonies.

Data from samples collected from pond were recorded (see table 2), which also depicted that EMF had microbial damaging effect that was evident from the total reduction of microbial colonies.

From the pumped-flow tube investigation, it was additionally evident that EMF exerted bactericidal effects, and the complete zero microbial colonies were found after 123 minutes EMF treatment.

In this study, it was found that if the sample water was treated for a short time (it may be 20 to 40 minutes) with a flow of electric current of 220 volts, very few microbial cell deaths were observed at that time as confirmed by counting the number of microbial colony counts in nutrient agar. In case of stationary tube method, uncountable numbers of colonies of the control sample (not treated in an electromagnetic field) were observed. However, the colony number was reduced to a range of 9-13 cfu/100il after 30

Table 1: Viable bacterial counts of lake (pond) water samples after stationary tube treatment

Experimental samples	Experimental design No (2)		
	Total treatment time (Minutes)	No. of turns	Viable bacterial count (cfu/100il)
Control	-	-	75±5
Pond ^{30min}	30	50	15±2
Pond ^{40min}	40	50	10±2
Experimental design No (3)			
Control	-	-	83±10
Pond ^{45min}	45	63	9±3
Pond ^{60min}	60	63	7±2
Pond ^{80min}	80	63	2±1

Control = without treatment in electromagnetic field (EMF). Data were presented as M±SD.

Table 2: Viable bacterial counts of tap water (A) and pond water (B) after pumped-flow tube treatment.

Experimental samples	Length of coil around the saline pipe (cm)	Drop/m	No of turns	Viable bacterial A	count (cfu/100il)
Control	-	-	-	60±5	90±8
(a)	120	40	715	7±2	12±8
(b)	120	35	715	4±3	7±3
(c)	120	30	715	1±1	4±4
(d)	120	25	715	0±1	0±1

Control = without treatment in electromagnetic field (EMF). Data were presented as M±SD. A = Tap water, B = Pond water.

to 40 min treatment through electromagnetic field. A drastic change was found when the treatment time ranged from 60-80 minutes and a sharp decrease in microbial cell death was found which was consistent with previous studies⁽⁶⁾. Similar result was also found in the pumped-flow tube method. This complies that electromagnetic field destroys water borne microbes. It is not very likely that the electrochemical mechanisms are the sole reasons for observed effects. The underlying biochemical effects of electromagnetic fields have not been clarified as of now¹⁶.

Living tissues are electrical conductors. In general, electrically conducting materials contain atoms and molecules with loosely bound electrons that can move from atom to atom under the influence of a force. Such movement, which will occur, for example, when an electric field is applied to the material, constitutes an electric current⁵. Usually, when a charged particle is exposed to an electromagnetic field, it will experience a force on it. Hence, all electrically charged particles in living tissues will experience forces when exposed to electromagnetic field. Because living tissues are conductors, these forces will cause electric currents to flow inside the body.

It was not clearly established whether the magnetic field has killed the bacteria in the several water samples. Theories are based on the biological effects of electromagnetic fields, and the possible effects on the permeability of the ionic channels in the membrane¹⁷. This can affect ions transported into the cells, and this can result in biological changes in the organisms. Other possible effect is the formation of free radicals due to magnetic

field exposure. The formation of radicals leads to temporary damage of cell membranes, including a modification of the ionic channel conductivity resulting in cell death¹⁸.

A group of scientists previously found that the DNA structure remains unaltered due to magnetic field¹⁹. It was also proved in the past that due to the exposure to EMF, DNA mutation has occurred¹⁵. Recently, Cellini *et al.*¹⁶ demonstrated that the exposure of *E. coli* to a 50 Hz electromagnetic field acts as a stressing factor, leading to phenotypical and transcriptional changes, and can be displayed as “cell death”. It was also found that EMF had no significant effect on metabolism⁶.

Previously it was shown that frequencies to stimulate ion or ionprotein complex to “swing” in a static magnetic field agree particularly well with those predicted for the biologically relevant ions—such as Ca²⁺, Mg²⁺, and Zn²⁺—by means of the ion-cyclotron resonance formula²⁰. The resonance frequency for Ca²⁺ ions is in the range of extremely low-frequency fields which is an indication for a possible interaction of biological systems and applied electromagnetic fields. The interaction of radicals and electromagnetic fields obviously caused damage to bacteria and these effects needs further investigation.

The water samples collected in this study were from a rich source of microbial areas (lake/pond), although tap water is not generally considered to be a source of microbial flora. It was found that exposure to short electromagnetic field killed water borne microorganisms for both stagnant and moving waters, and this seems to be consistent with previous findings^(5,7,21). Obtaining

sterile water is one of the burning issues in developing countries like Bangladesh. Conventional water purification technologies to treat polluted water are not that much reliable. Keeping in mind, we can say that this technology would be one of the most convenient and feasible ways to abate microbial load from water.

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