

Investigation of Antibacterial Effects of Electromagnetic Waves Emitted by Mobile Phones

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Received: 27 June 2012

Accepted: 19 August 2013

Abstract

It is known that antibiotics cause allergies in some people as well as their overdoses inducing kidney and liver failure. They may also cause side effects such as glossitis, stomatitis, nausea, vomiting, pseudomembranous colitis, diarrhea, skin erythema, and dermatitis. In this study, possible antibacterial effects of electromagnetic waves were investigated to find an alternative solution to antibiotics. To investigate antibacterial effects of electromagnetic waves, *E. coli* and *B. subtilis* were considered as example organisms. As a result of performed experimental studies, it was shown that electromagnetic waves suppress the growth of microorganisms.

Keywords: antibacterial effect, electromagnetic effect, mobile phone, *E. coli*, *B. subtilis*

Introduction

There are many studies in the literature about the effects of electromagnetic waves on living organisms [1-7]. The increase in the use of mobile phones in daily life and the decrease in the age of using them have focused this interest on mobile phones and their effects on human health [7-11]. Other reasons for the increase in interest are keeping and using these devices close to the vital organs [12].

Direct determination of the effects of electromagnetic waves emitted by mobile phones on human health is quite difficult. Therefore, the effects are tried to be determined indirectly. Performed studies are gathered in a few groups such as epidemiological studies [13], research performed on animal models [15] and cell studies [12].

In this study, unlike other researchers, possible antibacterial effects of electromagnetic waves emitted by mobile phones have been investigated, but not their harmful effects on human health. Today, antibiotics, including several active

substances, are used as antibacterials. It has been noted in the literature that some people are allergic to antibiotics as well as overdoses of them inducing kidney and liver failure, and they may also cause side effects such as glossitis, stomatitis, nausea, vomiting, pseudomembranous colitis, diarrhea, skin erythema, and dermatitis, depending on the antibiotic used [18, 19]. All these limit the use of antibiotics. However, it is known that the majority of patients lose their lives because of the infections caused by microorganisms since malignant diseases like cancer and AIDS destroy the immune system [16, 17, 20]. Therefore, finding alternative ways that may have effects on microorganisms is essential. In this publication, *E. coli* and *B. subtilis* were considered as example organisms in order to investigate antibacterial effects of mobile phones. Widely used cell phones were preferred as electromagnetic wave producers.

Biological Effects of Electromagnetic Waves

There is no direct relationship between the frequency and penetration of electromagnetic waves into tissues [8].

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It is necessary to determine the specific absorption rate (SAR) to be able to determine biological effects of electromagnetic waves, and especially cell phones. For this purpose, specific absorption rate (SAR) of tissues on structures prepared from special gels indicating the same electrical properties as tissues are tried to be determined [8, 15, 23]. Electric fields and magnetic fields generated by electromagnetic waves on tissues; create two kinds of effects: thermal and non-thermal.

Thermal effects are expressed as the change occurring in biological tissue as a result of conversion of energy of the electromagnetic wave absorbed by biological tissue into heat within the cell and the increase of the heat of the tissue. Electric and magnetic field vectors of the electromagnetic wave cause loaded molecules within biological tissue to move by applying a force to these molecules. At a certain frequency (900 MHz, 1800 MHz), heat energy is released as a result of the friction of molecules within the tissue by the deflection of these forces constantly and the interaction with the other molecules. This released heat continues until temperature compensation takes place by the tissue [8, 15, 23].

Non-thermal effects are the effects mostly generated by the wave as a result of its energy. Being of performed scientific studies reproducible will confirm the accuracy of performed investigations on this subject. Non-thermal effects of mobile phones on many subjects such, as their effects on DNA, their effects on the human sensory system, nervous system, brain tumors, their effects on bacteria, and their effects to protein synthesis are tried to be determined by experimental and epidemiological studies [1-5, 24-36].

Bacteria and Their Growth Stages

Bacteria are the simplest protists in which vital events take place. They are reproduced by division and they can maintain their lives without the assistance of another organism. With the discovery of the microscope, beside these organisms, existence of bacteria that are invisible to the naked eye was proven and studies on bacteria were also increased [2, 26]. Bacteria form a group that reproduces quickly unlike plants and animals and is of great importance in ensuring the balance of the living world in terms of their biochemical effects. Bacteria are the world's largest number of members [38, 41] and they affect human life in many ways. Bacteria propagate quickly, according to their species in an appropriate medium, at an appropriate temperature and environmental conditions [39, 40].

Propagation rates in bacteria differ depending on the species and environmental conditions. The overall growth curve of bacteria is shown in Fig. 1. Growth of bacteria occurs geometrically. Growth of bacteria planted in an appropriate broth is investigated in four phases. These phases are latent period, logarithmic period, standstill period, and death period [38, 41].

Latent Period

In this phase, propagation does not take place in bacteria incubated in the new medium. Bacteria try to be adapted to the medium. For this purpose, enzyme production and their metabolisms increase. A decrease in the number of bacteria can be seen because of deaths of bacteria that are not adapted to the medium. For bacteria that have adapted to the medium and prepared sufficient enzyme, organic and inorganic materials begin to propagate [38, 41].

Logarithmic Period

Bacteria that passed the latent phase begin to reproduce via dividing in certain generation times by certain intervals. Logarithmic phase curve of the bacteria is determined in this period with samples taken in certain intervals [38, 41].

Standstill Period

Propagation slows down as a result of the change of initial conditions in limited amount of broth where bacteria reproduce, the decrease of energy and nutrient and the increase of toxic wastes. Reproductive processes of bacteria are slowed down by the decrease of broth in the medium, the increase of metabolism wastes, and the increase of suppression in environmental conditions [38, 41].

Death Period

Bacteria begin to die after a while unless conditions such as the decrease of the nutrient amount in the nutrient medium, the slowdown of metabolisms change. Bacteria population begin to decrease in time. Bacteria that can maintain their vital functions by adapting to the formed new medium can be found. Therefore, the population is never zero. Growth stages of bacteria in the broth and their life curves are shown in Fig. 1 [38, 41].

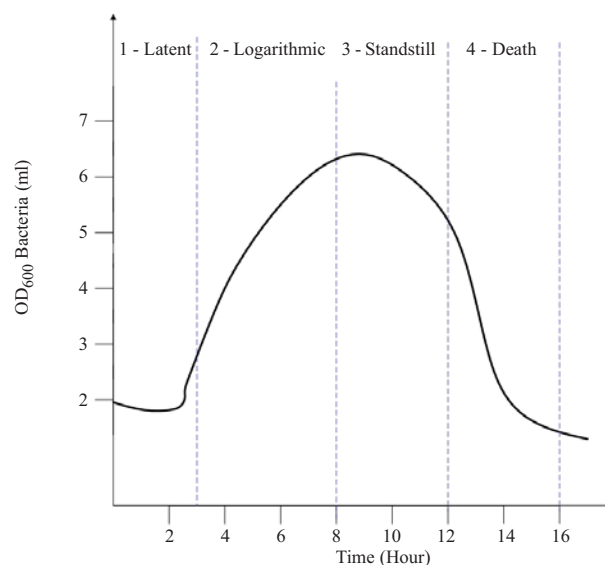


Fig. 1. Growth curve of the bacteria in broth [41].

In order to investigate antibacterial effects of electromagnetic waves, *E. coli* was chosen since it exists in human intestinal flora [39], and *B. subtilis* since it is a kind of bacteria that produces antibiotic and spore, protects itself against stressful mediums. It is also known that *B. subtilis* has a capsule whereas *E. coli* has no capsule [43]. In Fig. 1, the growth curve of the bacteria in the isolated broth to where electromagnetic waves were not applied is given.

Material Method

Materials

- 1) Bacteria: *E. coli* JM105 cells were kindly provided by Prof. Dr. Dilek Turgut-Balik and *B. subtilis* cells by Assist. Prof. Dr. Seher Gur.
- 2) Electromagnetic Field Exposure System: The system detailed by Akbal et al, [12] was used.
- 3) Laboratory: Experiments were performed in the molecular recognition laboratory in the Biology Department of Firat University, Faculty of Arts and Science.
- 4) Growth medium: Nutrient broth (meat peptone 5 g, meat extract 3 g) was used as 8 g/l. The sterilization process was performed at 121°C in an autoclave.

Methods

Experimental Setup

The setup used is that described by Akbal et al. [12] and given in Fig. 2. In this setup, a cell phone with 1 mW of antenna output power that works in GSM 1800 MHz was used. Interviews were made by mobile phones. This is because mobile phones work as DTX (discontinuous transmission). DTX is the system that provides data transmission only during the interview. At other times (in cases where no interviews take place) the receiving party in these systems hears nothing since there is no data transmission (data transmission will not occur). Therefore, an informative sign

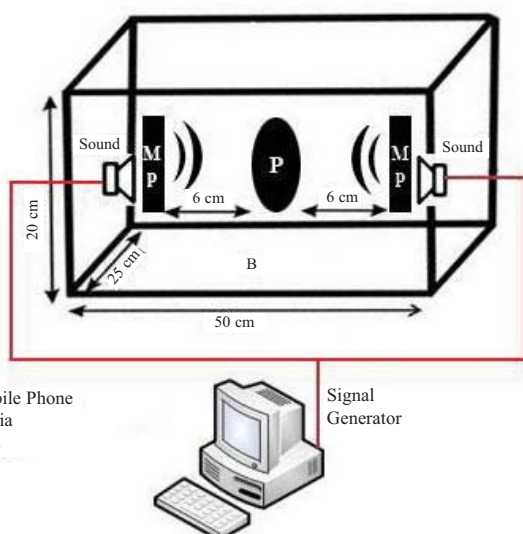


Fig. 2. Experimental setup [12].

was sent for the realization of the modulation during the interview in the experiment. This 4.6 ms of informative sign is sent with the help of a mobile phone by compressing it to 0.58 ms. A mobile phone and base stations send a 0.58 ms of pulse per 4.6 ms (ie, 217 pulses/second = 217 Hz). The energy transfer is also realized in this way.

Antennas of mobile phones that were used in the mobile phone experimental setup (constituted as in [12]) were prepared as toward biological substances to be exposed to the electromagnetic wave and placed into special places. The signal generator was connected to the audio input of the mobile phone. Afterward, the experimental setup was placed in the oven in order to avoid the heat generated by mobile phones during data transmission to change the ambient temperature and to maintain a constant temperature. Signals produced randomly with the help of a computer used as a signal generator were applied to mobile phones that were placed into the oven and realization of a data transmission was provided. Bacteria cells in the control group were incubated using an incubator that is in another laboratory ambient where no cell phones are used and different than those of the experimental setup.

Optical Density (OD) Measurement by Spectrophotometer

A spectrophotometer generates light with a desired wavelength and passes the light through a sample that is placed in a specially prepared cuvette and measures the intensity of the light passing through the sample. The sample to be measured is placed into these specially prepared cuvettes. Afterward, they are placed into a specially prepared chamber within the spectrophotometer apparatus. When the apparatus starts to run, the light from the light source with a wavelength adjusted according to the molecules to be measured focuses onto the chamber, and this light passing through the cuvette within the chamber is sensed by sensitive sensors. It gives the optical density (OD) value according to the amount of light sensed [43]. In this study, a spectrophotometer was used to measure the number of bacteria in the culture medium.

Experimental Study

In this study, experiments were performed to investigate whether electromagnetic waves have antibacterial effects.

First of all, it is necessary to grow bacteria in appropriate broth to study the effects of electromagnetic waves emitted by mobile phones on the growth of bacteria. The nutrient buyyon was prepared as described and used as the growth medium. Both bacteria were grown by using the same protocol. 5 ml of nutrient buyyon was inoculated with the appropriate bacterial cells and grown overnight at 37°C in a shaking incubator to obtain starting bacterial cultures. On the next day, 1 ml of the overnight bacterial culture was added to the fresh 200 ml buyyon and cells were allowed to grow to $OD_{600}:0.6$, or the value where bacterial culture reaches to the logarithmic phase [39, 41, 42]. This 200 ml

Table 1. Average OD₆₀₀ results of experiment and control groups for *E. coli* and *B. subtilis*.

Sample Time	Experiment Result			
	<i>E. coli</i>		<i>B. subtilis</i>	
	OD ₆₀₀ Result		OD ₆₀₀ Result	
	Control	Experiment	Control	Experiment
0. hour	0.627±0.0083	0,6673±0.0121	0.0125±0.0011	0.0120±0.0022
1. hour	0.899±0.0401	0,8567±0.0519	0.0165±0.0011	0.0200±0.0089
2. hour	1.240±0.0681	1,0870±0.1134	0.0470±0.0022	0.0535±0.0122
3. hour	1.435±0.1003	1,1017±0.0898	0.2045±0.0078	0.1715±0.0055
4. hour	1.617±0.0849	1,1400±0.0182	0.4540±0.0536	0.4025±0.0100
5. hour	1.740±0.1211	1,1067±0.0433	0.8495±0.0682	0.7710±0.0380
6. hour	1.763±0.0997	1,1000±0.0555	0.9035±0.0145	0.8440±0.0536
7. hour	1.780±0.0890	1,0367±0.0623	0.8830±0.0156	0.7655±0.0324
8. hour	1.787±0.0820	0,9733±0.0709	0.8330±0.0290	0.7420±0.0469
9. hour	1.757±0.0847	0,8600±0.0398	0.8110±0.0223	0.6845±0.0122
10. hour	1.767±0.0848	0,8433±0.0342	0.7390±0.0447	0.6470±0.0447

bacterial culture at OD₆₀₀:0.6 was divided in equal volumes into two sterile flask at completely sterile conditions. Then the first flask having the appropriate bacterial culture was exposed to the electromagnetic waves emitted by mobile phones at 1800 MHz in a shaking incubator at 37°C. The other half of the bacterial culture was placed into another shaking incubator at 37°C, in a different laboratory environment for the purpose of control. Samples were taken from these two groups of bacterial culture (control and experiment cultures) during the experimental application throughout 10 hours by intervals of one hour. OD₆₀₀ of

each samples were measured in the spectrophotometer without any delay and results of the measurement were recorded. All studies were performed in sterile conditions. Thus the effects of electromagnetic waves emitted by mobile phones on bacterial growth were tried to be determined properly. Experiments were repeated three times in order to show that the experiments to investigate effects of the electromagnetic waves on bacterial growth, and thereby its antibacterial effects, are reproducible, and to determine whether results are consistent. Results are given in Table 1.

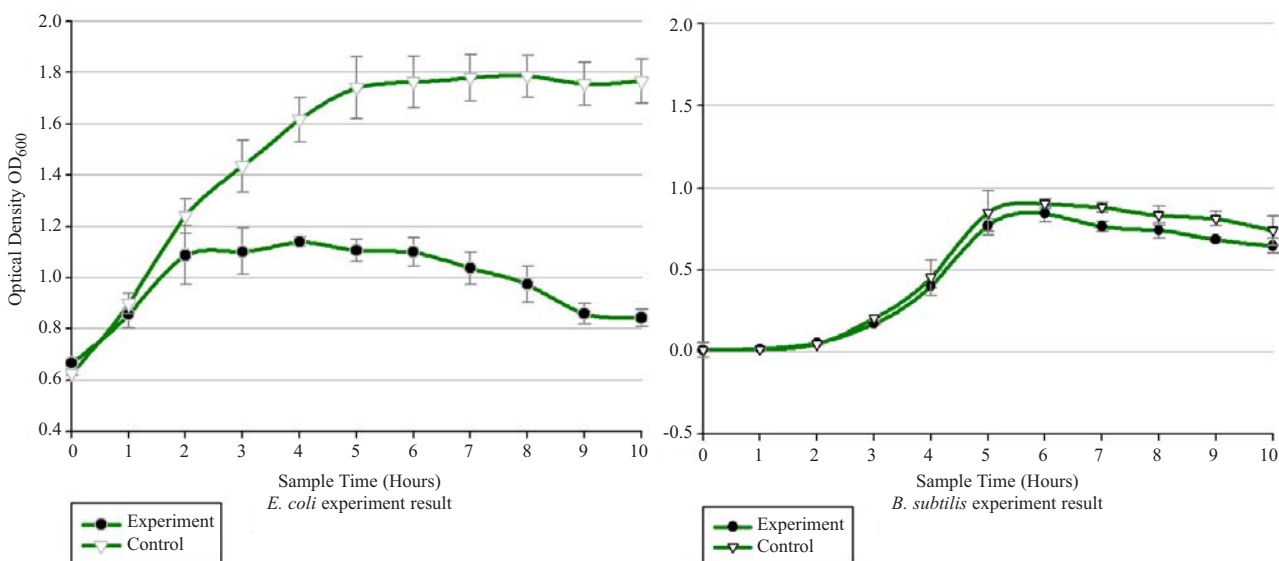


Fig. 3. Experimental results.

Experimental Results and Discussion

Experimental average OD₆₀₀ values of three repeats were given for both control and experimental groups for each bacterial species, *E. coli* and *B. subtilis* (Table 1). We performed three experiments to find out the effects of the electromagnetic wave on bacterial growth as given in Table 1.

Growth of bacteria in the latent period may present decreases from time to time because of deaths of bacteria at a high rate during the adaptation to the medium where they exist. The results after the bacteria have reached logarithmic phase were interpreted to avoid misinterpretation of bacterial deaths during the adaptation process to the medium in latent period of bacteria.

As seen in the experimental results belonging to *E. coli* and *B. subtilis*, the experiment was initiated after bacteria reached the logarithmic phase. Values in Table 1 and the standard error are seen graphically in Fig. 3.

As seen from the results, it was determined that *E. coli* and *B. subtilis* were affected by the electromagnetic wave. In the performed study, it was determined that electromagnetic waves affected the growth of *E. coli* and *B. subtilis*, and that bacteria tried to be adapted to the normal medium within the period until log phase (latent period), but bacteria exposed to the electromagnetic wave could not be adapted to the medium. It was determined that this case caused the experiment group of bacteria to reproduce less than the control group and reach death period earlier. However, it was observed that *E. coli* was affected by electromagnetic waves more in comparison to *B. subtilis*. *B. subtilis* is a bacteria known to have a capsule. Having *B. subtilis* (a capsule) and having *E. coli* (no capsule) were evaluated as the reasons for *B. subtilis* to be affected by electromagnetic waves less in comparison to *E. coli*.

Acknowledgments

We thank Prof. Dr. Dilek Turgut-Balık, Assist. Prof. Dr. Seher Gür, and Res. Assist. Venhar Çelik.

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