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Research article

Effect of antibiotics' electromagnetic spectrums on the bacterial growths: beyond drug-receptor interaction

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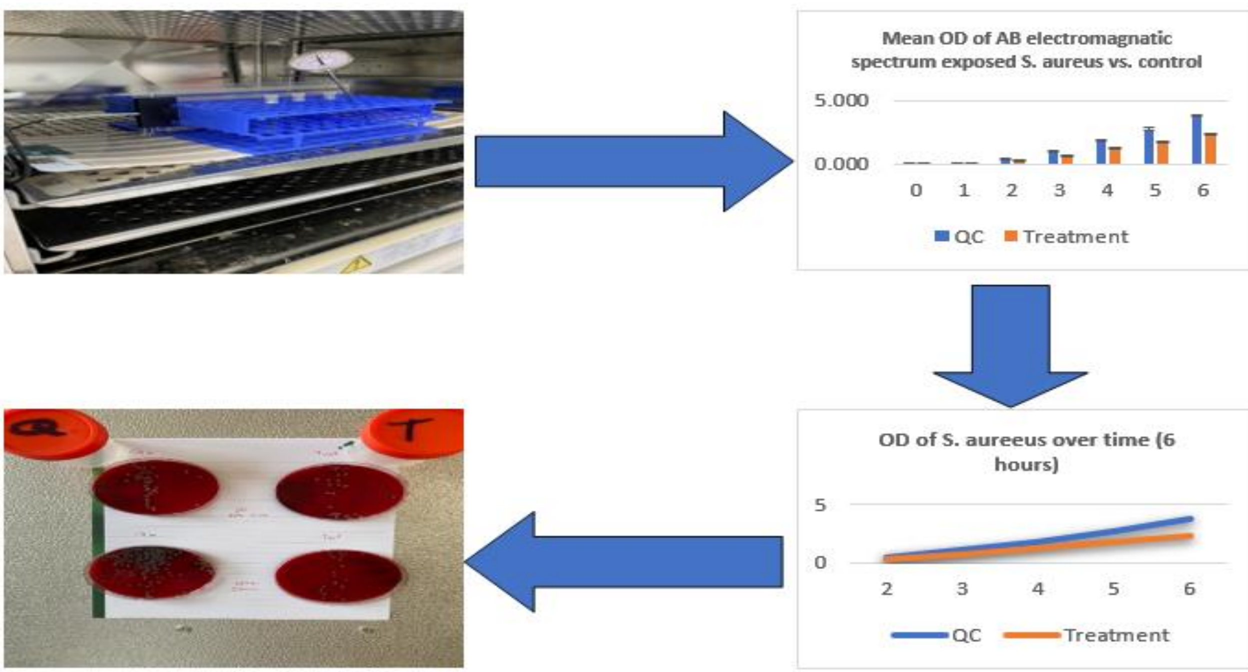
ABSTRACT



Electromagnetic frequencies (EF) generated from different laboratory devices and appliances can interact with biological systems, including humans. Several studies have assessed the effect of electromagnetic frequencies on the growth of microorganisms, which revealed that EF could inhibit bacterial growth, decrease colony-forming units, or decrease viability depending on the field strength and frequency. Accordingly, in this study, we aimed to assess the effect of the antibiotics extracted electromagnetic spectrums on the growth of *Staphylococcus aureus* (*S. aureus*). Drugs digital electromagnetic spectrums of a mixture of antibiotics were generated using a DigiConPro® VITATEC device emitted using the supplied antenna and applied into a glass tube containing nutrient broth inoculated with *S. aureus*, and optical density was measured hourly for 6 hours. The post-exposure effect of antibiotics' electromagnetic spectrums was also determined on bacteria subcultured into blood agar. Antibiotics' electromagnetic spectrums were seen to cause a statistically significant ($p<0.05$) decrease in the growth rate relative to the control after two hours of exposure that persisted until the stationary phase was reached. Also, this effect persisted after exposure and affected the next generation of bacteria and 4 hours dose of antibiotics' electromagnetic spectrums was able to induce a huge reduction (5 times) in the bacterial growth compared to the control group and in reference to the zero time. As a conclusion, electromagnetic spectrums of the medications may have the same effect as the chemical compound, and the mechanism of drug action can be explained beyond the simple chemical-receptor interaction.

Keywords: Electromagnetic radiation, Antibiotics, Infection, Post-exposure, Biological organisms.

INTRODUCTION

It is well-documented and approved that electromagnetic radiation can generally interact with biological systems, including humans.[1-3] For many decades, the field of non-ionizing, non-thermal electromagnetic radiation has drawn the most attention and is the focus of discussions on whether the radiation of mobile phones and the electricity supply net may be harmful or not and on the other hand, whether therapeutic effects can be created by such radiation.[4]

The frequency range of non-ionizing electromagnetic radiation is immense, ranging from 1 Hz to visible light, and encompasses 15 decades. In comparison, This large bandwidth of electromagnetic radiation makes systematic research of the effects of electromagnetic radiation on biological organisms practically impossible.[5] We can have infinite single frequencies, combinations of frequencies, bandwidths, pulse shapes, pulse trains, and intensity variations on the emitter side. On the other hand, there are very large varieties of biological structures, membranes, single macromolecules, etc., on the receiver side, which all might be potential antennas for specific signals.[6]

Research on possible therapeutic effects has for one part concentrated on the range of visible light and near-infrared, and for another part has been carried out with very different pulse shapes and antennas based on specific ideas of the researchers.[7] The main frequencies of the latter can be found in the Hz, kHz, or MHz region. A few of these specific signals have attained medical approval and have been used unaltered for many years for some therapeutic applications [8, 9]. However, in summary, due to the infinite number of possible signals and interactions, the search for signal shapes with therapeutic relevance is empirical.

One well-known class of signals is called PEMF (Pulsed Electromagnetic Frequencies). The used antennas are coil-like. With the signals, a steep magnetic pulse is produced by the coils, which in turn creates a pulsed electric field in the tissue that is supposed to have therapeutical benefits. Such equipment has been used for many years in the field of bone healing and related topics. A different rationale behind the use of specific frequencies is ICR (Ion Cyclotron Resonance). The frequencies in the applied signal are tuned in such a way that ICR occurs between the applied frequency, the local magnetic field, and the mass/charge ratio of a specific ion in the tissue. The idea behind this is to enhance the movement of the specific ion.[8]

Many studies have assessed the effect of electromagnetic signals on the growth of microorganisms (e.g., *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*)), which revealed that these signals could inhibit bacterial growth, decrease colony-forming units, or decrease viability depending on the field strength and frequency. In some of those studies, antibiotics were involved. The goal of these studies was to find out whether the effects of antibiotics on such colonies could be enhanced by the application of certain electromagnetic signals. In several cases, large effects have been found, indeed.[10-13]

The rationale of our study is based on the assumption that interactions between molecules in cells are not only of a biochemical nature. We suppose that an electromagnetic part is present as well, basically consisting of the resonance frequencies (eigenfrequencies) of the reaction partners involved. Following this idea, we aimed to investigate whether the biochemical effect of specific substances on organisms might be simulated by the effect of electromagnetic signals consisting of their eigenfrequencies.

In this study, we present the effects of a very weak broadband electromagnetic signal derived from several antibiotic substances. These signals had been obtained previously by placing the substances during a certain time in a well-screened receiver antenna with a bandwidth from about 1Hz to 4 GHz. After that, they were digitalized and stored in computer memory. The procedure of obtaining the signal is not part of the present study. Here we present the result of the application of the combined signal to the growth of the bacterium *S. aureus*. The *null hypothesis* is that the application of this signal does not affect bacterial growth, while the alternative hypothesis is that it can significantly inhibit bacterial growth.

MATERIALS AND METHODS

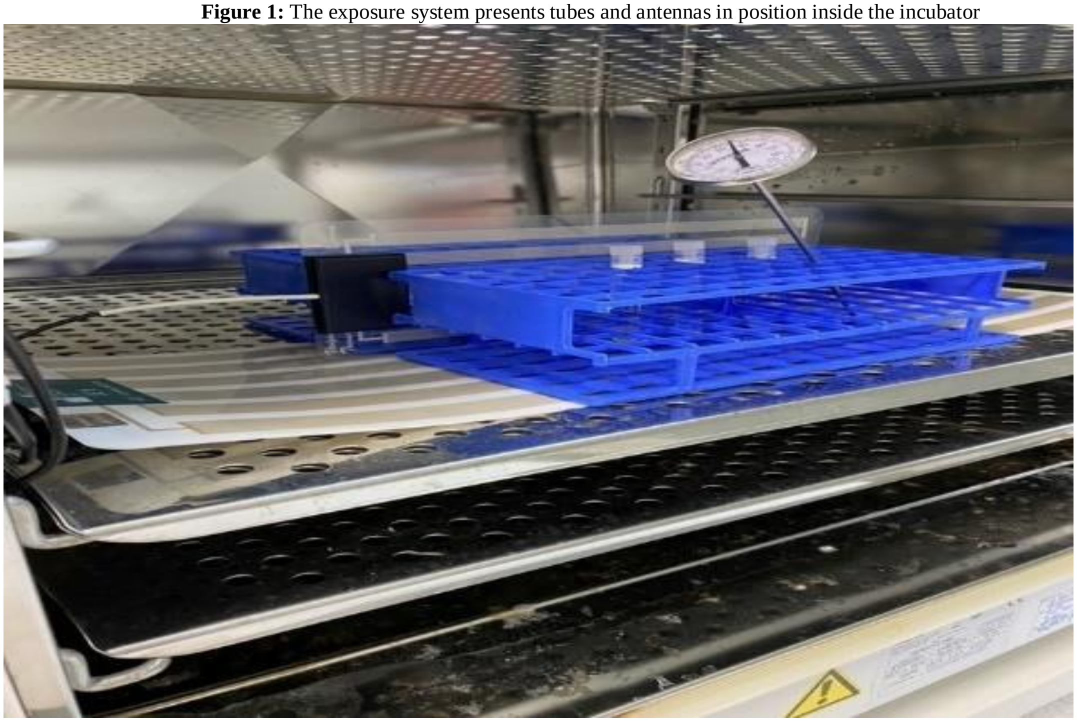
Electromagnetic spectrum generation and exposure system

Drugs' digital electromagnetic spectrums of a mixture of antibiotics were generated using a DigiConPro® VITATEC (Model No.: D131001) device and emitted using the supplied antenna. The antennas positioned parallel to the ground generated a digital vertical magnetic field on the sample dish (6 ml glass tubes containing 3 ml of nutrient broth). The exposure system was placed in an incubator at 30C. At the same time, the control tubes were not exposed to electromagnetic fields and were placed in another incubator in a different lab under the same conditions to prevent any field contamination. The electromagnetic generator device DigiConPro® VITATEC was turned on at least 1 hour before starting the exposure to achieve field stability and consistency.

Bacterial stain and Bacterial growth assay Staphylococcus aureus (American Type Culture Collection (ATCC25923) was used to study the effect of antibiotics' electromagnetic spectrums on bacterial growth. *S. aureus* was kept at -80°C, and fresh cultures were prepared for the experiment.

S. aureus was incubated into the nutrient broth and incubated at 37°C overnight for cultivation. Then *S. aureus* was reinoculated into a fresh nutrient broth medium and incubated for another 18 hours to get logarithmic phase cultures. *S. aureus* was subcultured into two sets (3 tubes of each) of 10mL fresh nutrient broth-containing tubes to obtain 1 X 10^5 colony-forming units (CFU) per ml. One set of tubes was placed into the magnetic field antenna and subjected immediately to antibiotics' electromagnetic spectrums within an incubator at 30°C. In contrast, control tubes were placed in the same conditions as those exposed without electromagnetic spectrum application [Figure 1]. *S. aureus* growth was determined concurrently for both exposed and control tubes by measuring optical density (OD) at 600nm using DensiCHEKplus® at 0, 1, 2, 3, 4, 5, and 6 hours of continuous exposure. All measurements were made twice for the three samples of each group to ensure accuracy and consistency.

Figure 1: The exposure system presents tubes and antennas in position inside the incubator



To determine the post-exposure effect of antibiotics' electromagnetic spectrums on the *S. aureus* growth, 1 µl from control and exposed *S. aureus* suspension was collected at both 0 and 4 hours (mid-log phase) and subcultured in blood agar using spreading techniques. The plates were incubated for 24 hours at 37°C, then bacterial growth and the number of colonies were assessed.

Statistical analysis

Data were presented as *mean* ±standard deviation. Statistical significance for the change in the growth of exposed and control samples over time was evaluated using the Fridman test. Statistical significance for the difference in the growth between exposed and control samples was determined using the Mann-Whitney U test, and the p-value was set at $p<0.05$ for all tests. All data used in the study were analyzed using SPSS 25.0 (IBM SPSS Statistics for Windows, Version 25.0 IBM Corp., Armonk, NY, USA).

RESULTS

Effect on S. aureus growth rate and OD reading

Three *S. aureus*-containing tubes were exposed to electromagnetic spectrums of a mixture of antibiotics for 6 hours, and the Optical density (OD) measurement was taken every hour for both sets (exposed and control). For both sets, exposed and control, growth in time was found to be significant according to the Fridman test [Figure 2 & Table 1].

Table 1: Fridman test for Statistical significance for the change in growth over time

Bacteria	N	Chi-Square	Df	P-value
QC	3	18	6	0.006**
Treatment	3	18	6	0.006**

**p<0.01 is statistically very significant

The OD for both antibiotics' electromagnetic spectrum exposed bacteria and control was presented in [Figure 3 & Table 2]. Antibiotics' electromagnetic spectrums were seen to cause a statistically significant ($p<0.05$) decrease in the growth rate relative to the control after two hours of exposure that persisted until the stationary phase was reached.

Figure 2: Average OD of *S. aureus* containing tubes (Treatment vs. QC)

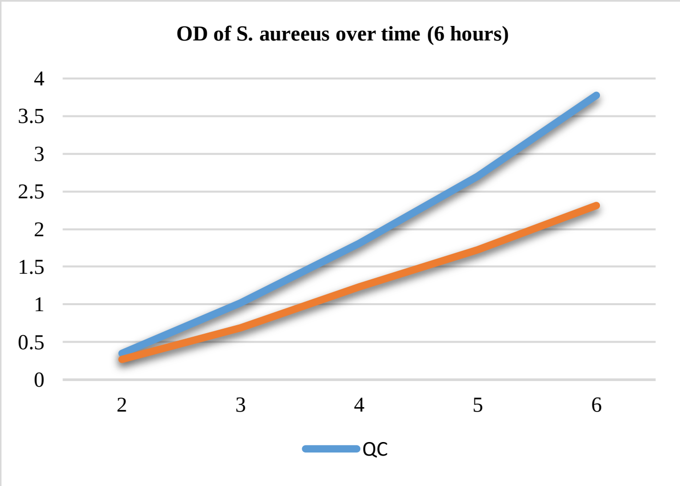


Figure 3: Mean OD of antibiotics' electromagnetic spectrum exposed *S. aureus* vs. control

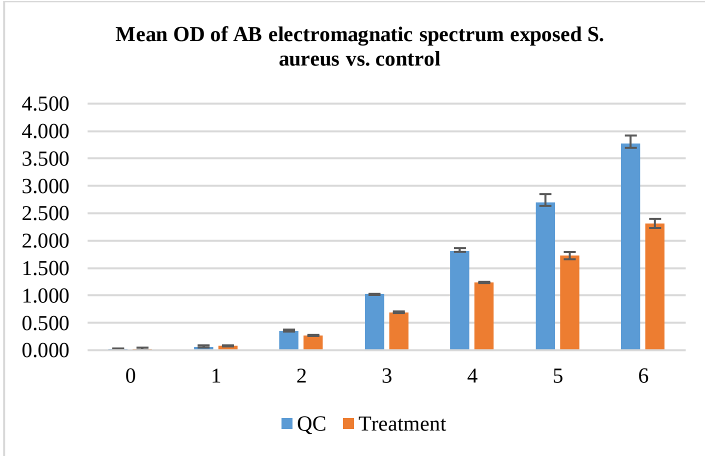


Table 2: OD (mean ±SD) of antibiotics' electromagnetic spectrum exposed *S. aureus* vs. control

Time	QC (mean ±SD)	Treatment (mean ±SD)	Mann-Whitney U	Z	P_value
0 hr	0.027 ±0.006	0.027 ±0.021	3.500	-.449	0.653
1 hr	0.060 ±0.030	0.080 ±0.010	2.500	-.886	0.376
2 hr	0.350 ±0.026	0.270 ±0.010	0.000	-1.964	<0.05*
3 hr	1.023 ±0.006	0.693 ±0.015	0.000	-1.993	<0.05*
4 hr	1.807 ±0.057	1.237 ±0.012	0.000	-1.993	<0.05*
5 hr	2.700 ±0.149	1.727 ±0.67	0.000	-1.964	<0.05*
6 hr	3.777 ±0.142	2.313 ±0.083	0.000	-1.964	<0.05*

*p<0.01 is statistically very significant

Figure 4: Effect of antibiotics' electromagnetic spectrums (0 and 4 hours) on the *S. aureus* bacterial growth in blood agar plates after 24 hours incubation at vs. control presented by CFU/mL

Effect on *S. aureus* growth in blood agar palate

The significant decrease in the growth rate of the exposed *S. aureus* led us to evaluate whether the effect of the antibiotics' electromagnetic spectrums will continue following exposure. Accordingly, zero and 4 hours exposed, and control *S. aureus* were subcultured in blood agar and incubated for 24 hours. The results revealed that the inhibition induced by antibiotics' electromagnetic spectrum persisted after exposure and affected the next generation of bacteria and 4 hours dose of antibiotics' electromagnetic spectrum was able to induce a huge reduction in bacterial growth compared to the control group and in reference to the zero time. This reduction in bacterial growth was presented by CFU/ml [Figure 4]. After 24 hours of incubation, there was around 5 times increase in the number of CFUs/mL in the control samples, where the number of CFU/ml of *S. aureus* exposed for four hours dose of antibiotics' electromagnetic spectrums remained almost constant.

DISCUSSION

Several studies have assessed the effect of different electromagnetic frequencies on bacterial growth.[2, 14, 15] However, our study is unique as it is the first study that assesses antibiotics' electromagnetic spectrums' effect on bacterial growth. Garip et al. evaluated the impact of an extremely low-frequency electromagnetic field (50 Hz for 6 hours) on the growth rate of three gram-positive and three gram-negative bacteria and found a significant decrease in the growth rate of three gram-positive and three gram-negative bacteria and found a significant decrease in the growth rate with respect to control samples and the reduction in the growth rate continued for progeny after exposure. On the other hand, Occul et al. in research aimed to determine the effect of extremely low electromagnetic fields (50 HZ) on *S. aureus* and *E. coli* membrane potential, surface potential, hydrophobicity, respiratory activity, and growth after two hours of exposure, noticed that electromagnetic spectrums have the potential to change physiochemical properties of both gram-positive and gram-negative bacteria with an increase in its respiratory activity and decrease its growth rate.[14] Furthermore, Strasak et al. in research aimed to assess the effect of low-frequency magnetic fields of 50 Hz for a shorter time (12 minutes at room temperature) on the viability and oxidative activity of *E. coli* noticed that the growth was negatively affected in comparison to the control *E. coli* and the ability of *E. coli* to form colonies decreased with increasing magnetic field intensity and time of exposure.[15]

The promising results of our study furnish a new concept of treatment that the electromagnetic spectrums of the medications may have the same effect as the chemical compound, and the mechanism of drug action can be explained beyond the simple chemical-receptor interaction. However, the study has some limitations as i. The need for a suitable control to confirm that the inhibition effects were seen is solely due to the antibiotics' electromagnetic spectrum and not due to exposure to any electromagnetic fields in general. ii. The need for more specific cellular assay tests to identify the exact mechanism of the bacteriostatic/ bactericidal effect of the antibiotics' electromagnetic spectrums. iii. The need to study the effect of the antibiotics' electromagnetic spectrum on bacterial morphology and bacterial internal organs.

CONCLUSION

Antibiotics' electromagnetic spectrums showed promising results in reducing *S. aureus* growth rate and the number of colony-forming units. These results need further research to identify the mechanism of bactericidal/bacteriostatic effect.

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Declaration of Conflict of Interest

The authors declare that they do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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