



## Radiological Impact of Smartphone Usage on Antibiotic Resistance in Ear Microbiota: A Cross-sectional Study

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### ABSTRACT

**Background:** Extended use of mobile phones has been found to cause harm to the inner ear, as indicated by the discovery that individuals who frequently use cell phones exhibit measurable hearing loss that may not be immediately noticeable.

**Objective:** This study aims to analyze and determine the radiological impact of smartphone radiation on the enhancement of the resistance of indigenous bacterial flora.

**Methods:** A cross-sectional study was conducted, collecting a total of 100 ear swab samples from students at Diyala University. Participants were recruited from three distinct academic departments: Science (n=52), Geography (n=33), and Sports (n=14). For each participant, relevant demographic and clinical data were documented to facilitate subsequent analysis.

**Results:** Microbiological isolation and identification tests revealed the following prevalence of bacterial species: *Staphylococcus epidermidis* (45.3%), *Enterobacter* spp. (20.0%), *Pseudomonas* spp. (17.3%), *Escherichia coli* (10.0%), and *Proteus* spp. (6.6%). Antimicrobial susceptibility testing demonstrated distinct resistance profiles. The highest resistance was observed in *Staphylococcus epidermidis* to Cefoxitin (CX), *Enterobacter* spp. to Amoxicillin-Clavulanic acid (AMC), *Pseudomonas* spp. to Clindamycin (DA), and *Escherichia coli* to AMC. *Proteus* spp. exhibited high-level resistance to both DA and AMC. Furthermore, exposure to mobile phone radiation was associated with a measurable alteration in the diameter of inhibition zones for all tested bacterial species, with the magnitude of effect varying between genera.

**Conclusion:** The study found that bacteria from students showed varying antibiotic resistance, with *Staphylococcus epidermidis* being the most common and resistant. Mobile phone radiation caused noticeable changes in bacterial inhibition zones, suggesting a possible link between radiation exposure and increased antibiotic resistance.

**Keywords:** smartphone radiation, microbiota, bacteria, antibiotic resistance, student case.

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## INTRODUCTION

### The General Health Impacts of Mobile Radiation

Decades ago, there was a significant increase in the number of electromagnetic radiation sources, including portable telephony installations at bases and cell phones. The World Cancer Research Fund classifies such radiation as a potential human carcinogen (Group 2B), prompting extensive

research on the effects of mobile phones on human health (1). The research on radiofrequency radiation has focused primarily on its potential and impacts on human health, specifically with regard to the brain, cancer risk, and fertility (2). This impact has been identified as a range of effects, including the activation of specific enzymes and nervous system signals, as well as toxicological, genotoxic, and carcinogenic effects (3).

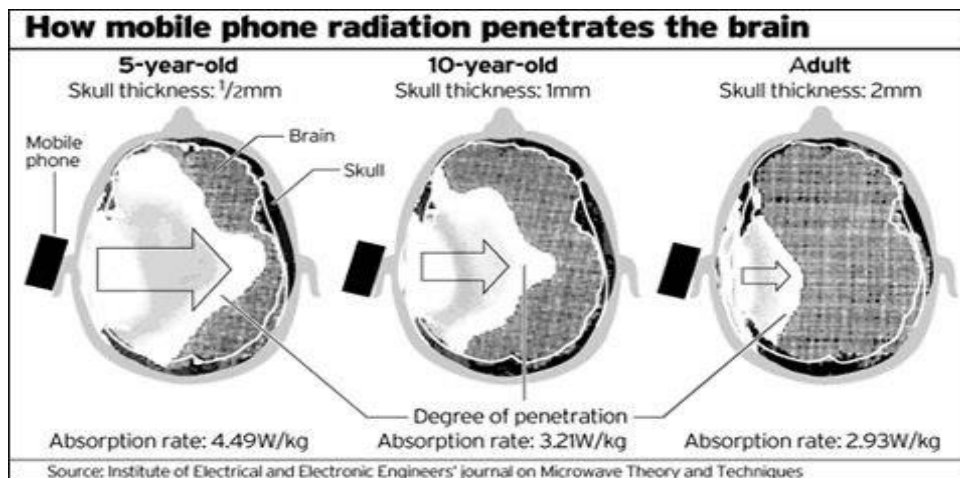


Figure 1: The effect of mobile radiation on the human brain (4).

The Specific Absorption Rate (SAR) is utilized to measure the rate at which radiation penetrates the body and has been established at a maximum value of 1.6 to 2 W/kg per gram of tissue for current handheld devices (2). When the head and ears are situated within the "near field" zone of radiation, there is a possibility of thermal and non-thermal impact on the body if the SAR exceeds the allowed limit (2). The thermal effect of microwaves on any dielectric material, such as living tissue, is caused by the

rotational movement of polar molecules inside the tissues, such as water (5). The effect of radiofrequency radiation on various cellular components such as mitochondria, apoptotic pathways, heat shock proteins, free radical metabolism, cell growth, cell differentiation, DNA damage, and the plasma membrane has been extensively investigated in the published literature (6, 7).



Figure 2: Effects of mobile phone use on human health. Changes may occur in the cardiovascular and reproductive systems, as well as the central nervous system (6).



Extended use of mobile phones has been found to cause harm to the inner ear, as indicated by the discovery that individuals who frequently use cell phones exhibit measurable hearing loss that may not be immediately noticeable. This observation is more in line with the effects of radiation exposure (8). The bilateral nature of the damage suggests that it may be attributable to a radiation effect rather than solely to persistent loud noise exposure in one ear. The ear canal potentially serves as “a natural conduit via which radiated radiofrequency radiations may reach the peripheral and central nervous system” (8). The proliferation of mobile devices has prompted discussions on the potential hazards they pose, particularly with regard to the effects of high-frequency electromagnetic fields (EMFs) on health. The major frequency range for mobile phone microwave radiation transmission and reception is 800 to 2,000 MHz (9).

### Special Effects of Mobile Radiation on Micro-Organisms

Recent research has demonstrated that microorganisms exposed to RF-EMFs can experience a wide variety of modifications, from altered bacterial growth to altered antibiotic resistance patterns (10). Exposure to mobile phone radiation has been found to cause harm to both humans and other living organisms. In this study, the focus was on the effect of such radiation on the susceptibility of specific bacteria to antibiotics. The results indicate that bacteria exposed to mobile phone radiation exhibit reduced sensitivity compared to those that have not been exposed (11).

### The Microbial Content of the Ear

*Staphylococcus capitis* and *S. capitis/caprae* are present in the healthy ear core microbiome, but *Aspergillus* species, *Candida* species, *Pseudomonas aeruginosa*, *S. aureus*, and *Corynebacterium jeikeium* are present in the sick ear core (12). Ear infections, whether acute or chronic, are commonly encountered conditions that prompt patients to seek medical attention and receive antibiotics (13). Otitis externa (OE) and otitis media (OM) are the most typical types of ear infections. Otitis media, commonly referred to as OM, is characterized by the accumulation of fluid in the subtympenic region, resulting in middle ear irritation. This irritation is triggered by the

proliferation of pathogenic strains of bacteria, fungi, and/or viruses. The ensuing inflammation manifests as infection, swelling, redness, and discomfort (14).

### Specific Absorption Rate and Biological Impact of Mobile Radiation on Microbiota and Antibiotic Resistance

The Specific Absorption Rate (SAR) is a measure of the rate at which the body absorbs energy from an electromagnetic field, particularly radiofrequency (RF) radiation emitted by mobile devices. The SAR is typically expressed in watts per kilogram (W/kg), and international guidelines such as those from the International Commission on Non-Ionizing Radiation Protection (ICNIRP) limit SAR values to prevent harmful thermal effects (3). Exposure to mobile phone radiation has been shown to cause biological effects at the cellular and molecular levels, including oxidative stress, DNA damage, and changes in gene expression. Several studies report that chronic exposure to RF-EMF can alter the structure and function of bacterial communities and may enhance bacterial stress responses (15). In the context of the ear microbiota, prolonged and repeated exposure to mobile radiation—especially when phones are in close contact with the ear—can influence the composition and behavior of microbial communities residing in the external auditory canal. Research suggests that RF radiation may not only shift the microbial balance but also contribute to increased expression of antibiotic resistance genes (ARGs). This occurs possibly through enhanced horizontal gene transfer (HGT) and stress-induced mutations in the microbial DNA (16). Therefore, the localized exposure of the ear to mobile phone radiation, measured by SAR, could be a contributing factor to the development of antibiotic-resistant microbiota in that region.

## METHODOLOGY

### Sample Collection

A total of 100 samples were collected from students of the College of Basic Education, departments of science, geography, and sports from Diyala province, Iraq. Among these samples, 52 were from the science department, 33 from the geography department, and 14 from the sports department. For each student, a sample was obtained from their ear using a sterile cotton swab. A unique identifier was assigned to each



sample, and data was recorded on an information form for each student.

### Media Preparation for Culture

In accordance with the manufacturer's guidelines, the culture medium employed in the research underwent sterilization within an autoclave at a temperature of 121°C and 15 psi pressure for a duration of 15 minutes. Subsequently, to ensure the plates remained free from microbial contamination, the medium was carefully transferred onto sterile dishes within a biological safety cabinet and subsequently incubated for a period of 24 hours.

### Isolation of Bacteria and Identification

A 5 ml portion of nutrient broth medium was seeded with bacteria and then placed in an incubator at 37°C, as described by (17). Following incubation, a 0.1 ml aliquot of the inoculated broth was aseptically transferred to two distinct agar types: blood agar and MacConkey agar. These agar mediums are frequently used for evaluating the health of individuals in the age group of 18 to 24 years. The bacterial colonies were identified through the analysis of their morphological attributes, including their shape, color, surface characteristics, hemolysis patterns observed on blood agar medium, and lactose fermentation on MacConkey agar media, as detailed by (18). Furthermore, bacterial isolates derived from the growing colonies on the culture media underwent fixation and staining using Gram's stain. Subsequently, a microscopic examination was conducted to assess cell arrangements and shapes, determine the response to the stain (positive or negative), and evaluate the presence of capsules. Additionally, the formation of biofilms was examined, and biochemical tests were employed to differentiate between positive and negative bacteria. The Vitek system used to confer bacterial diagnosis.

### Antibiotic Resistance Test

To ensure a consistent inoculum is prepared from a bacterial culture, McFarland standards are utilized to standardize the bacterial solution. This standardized bacterial suspension is then introduced into a specific culture medium, such as Mueller Hinton Agar (MHA) for disk diffusion tests. After the antimicrobial disks have been added, the petri dishes are incubated, and the zone of inhibition is measured to interpret the results of Antimicrobial Susceptibility Testing (AST), as outlined by (19).

### Study the Effect of Mobile Radiation on Bacterial Species

This experiment aimed to assess the influence of mobile radiation on bacterial species' antibiotic resistance. This was achieved by measuring inhibition diameters both before and after radiation exposure and capturing images to visualize changes in resistance levels. Bacterial species exhibiting increased resistance were specifically chosen for analysis to evaluate how radiation affects their susceptibility to antibiotics.

### Statistical Analysis

The data are expressed as means  $\pm$  SD, where n refers to the number of students. Statistical comparisons between the means of mild and prolonged exposure to EMR of mobile phones and those of normal usage were carried out by T-test using SPSS version 16. Significance was determined at  $p < 0.05$ .

### RESULTS

Tables (1 and 2) show the distribution of samples by university level and department, with the science department receiving the most samples (52) from students, followed by the geography and sports departments (33, 14). Males (55) and females (55), respectively (44).

Table 1: The number of samples taken from the permission of undergraduate students, distributed according to departments and stages

Section	Stage 1	Stage 2	Stage 3	Stage 4	Total
Science	12	12	13	10	52
Geography	11	8	8	6	33
Sports	0	0	0	14	14



Table 2: Distribution of samples taken by gender

Section	Stage 1		Stage 2		Stage 3		Stage 4		the total	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Science	6	6	6	6	9	4	8	7	29	23
Geography	11	0	5	3	3	5	5	6	19	14
Sports	0	0	0	0	0	0	7	7	7	7
Total	23		20		21		35		55	44

Table (3) clearly displays that the total sample size of 100 is comprised of both positive samples for culture (75) and negative samples for culture (25). Table (4)

shows the distribution of bacterial species in proportion to the total number of samples that tested positive for culture.

Table 3: Number of samples that tested positive for culture

Culture samples	Number	Percentage%
Culture positive samples	75	75 %
Culture negative samples	25	25 %
<b>Total number of samples</b>	<b>100</b>	<b>75 %</b>

Table (4) presents the distribution of bacterial species in relation to samples that were culture-positive, with a total of 75 samples and the types of *Staphylococcus epidermis* (34), *Enterobacter* (15), *Pseudomonas* (13), *E. coli* (8), and *Proteus* (5) bacteria. It also depicts the distribution of bacterial species in samples that tested positive for culture. Out

of a total of 75 samples, *Staphylococcus epidermis* was found in 34 samples, *Pseudomonas* in 13 samples, *E. coli* in 8 samples, and *Proteus* in 5 samples. While Table (5) illustrates the sex distribution of bacterial species in samples that tested positive for culture.

Table 4: The distribution of bacterial species in proportion to the total number of samples that tested positive for culture.

Isolate type	Number	Percentage %
<i>Staphylococcus epidermis</i>	34	45.3
<i>Enterobacter</i>	15	20
<i>Pseudomonas</i>	13	17.3
<i>E. coli</i>	8	10
<i>Proteus</i>	5	6.6
<b>Total</b>	<b>75</b>	<b>100 %</b>

Table 5: The bacterial species' sex distributions.

Isolate type	Male		Female	
	Number	Percentage %	Number	Percentage %
<i>Staphylococcus epidermis</i>	23	53.4	12	37.5
<i>Enterobacter</i>	8	18.6	9	28.1
<i>Pseudomonas</i>	2	4.6	10	31.2
<i>E. coli</i>	5	11.6	1	3.1
<i>Proteus</i>	5	11.6	0	0
Total	43		32	

Table (6) illustrates clearly the distribution of bacterial species in relation to the number of hours mobile phones are used. The highest number of usage falls within the 1–6 hour range, with a total of 67

bacterial species identified. Among these species, *Staphylococcus epidermis* was found to have the highest number at 29, followed by *Enterobacter* at 15, *Pseudomonas* at 12, *E. coli* at 6, and *Proteus* at 5.



Moving on to the 6-12 hour range, there were only two identified bacterial species, both belonging to *Staphylococcus epidermis*. In the following range of 12-18 hours, a total of four bacterial species were identified: two from *Staphylococcus epidermis* and

two from *E. coli*. Lastly, there were only two identified bacterial species in the range of 18-24 hours—one from *Staphylococcus epidermis* and one from *Pseudomonas*.

Table 6: The distribution of bacterial species in relation to the amount of time spent using mobile phones.

The number of hours	The number of bacteria	<i>Staphylococcus epidermis</i>	<i>Enterobacter</i>	<i>Pseudomonas</i>	<i>E. coli</i>	<i>Proteus</i>
(1-6)	67	29	15	12	6	5
(6-12)	2	2	0	0	0	0
(12-18)	4	2	0	0	2	0
(18-24)	2	1	0	0	0	0
<b>Total</b>	<b>75</b>	<b>34</b>	<b>15</b>	<b>13</b>	<b>8</b>	<b>5</b>

Table (7) presents the distribution of bacterial species in relation to the ear used, indicating that *Staphylococcus epidermis* is the most prevalent type, with a total of 35 isolates, of which 28 were found in the right ear and 7 in the left ear. *Enterobacter* is the second most frequent type with 17 isolates, of which only one was found in the left ear. *Pseudomonas*

follows with 12 isolates, of which 9 were found in the right ear and 3 in the left ear. *E. coli* is present with a total of 6 isolates, one of which was found in the right ear and five in the left ear. Finally, *Proteus* accounts for five isolates, four of which were found in the right ear and one in the left ear.

Table 7: The distribution of bacterial species by ear.

Type of bacteria	Number of isolates	Right ear	Percentage%	Left ear	Percentage%
<i>Staphylococcus epidermis</i>	35	28	80	7	20
<i>Enterobacter</i>	17	16	94.1	1	5.8
<i>Pseudomonas</i>	12	9	75	3	25
<i>E. coli</i>	6	1	16.6	5	83.3
<i>Proteus</i>	5	4	80	1	20
<b>Total</b>	<b>75</b>	<b>58</b>	<b>77</b>	<b>17</b>	<b>23</b>

The sensitivity test results revealed that *Staphylococcus epidermis* exhibited the greatest resistance to ampicillin and cefoxitin (CX), while

*Enterobacter* was most resistant to amoxicillin (AMC), as shown in Table (8).

Table 8: Antimicrobial susceptibility pattern of bacterial isolates.

Type of bacteria	Number of isolates	Type of antibiotics					
		RA	OX	VA	AM	CTR	CX
<i>Staphylococcus epidermis</i>	34	24 %	29 %	24 %	91 %	21 %	88 %
<i>Enterobacter</i>	15	DA	S	TOB	AMC	NA	TE
		27%	7%	0%	33%	0%	7%
<i>Pseudomonas</i>	13	62 %	38 %	31 %	62 %	31 %	31 %
<i>E. coli</i>	8	38 %	13 %	13 %	50 %	13 %	13 %
<i>Proteus</i>	5	40%	0%	0%	40%	20%	0%

*Pseudomonas* showed high resistance to Clindamycin (DA) and Ampicillin (AM), and *E. coli* was most resistant to Amoxicillin (AMC). Finally, the bacteria

*Proteus* demonstrated significant resistance to both Clindamycin (DA) and Amoxicillin (AMC). The graphs presented below, accompanied by images, indicate a



significant difference in the inhibition diameters for various types of antibiotics. These results were obtained from bacterial species identified and isolated from the ear after exposure to mobile radiation for specific periods. The observed decrease

in inhibition diameters suggests an increase in the resistance of bacteria to radiation-induced effects. Figures 3 and 4 illustrate a reduction in the inhibition diameters of VA, OX, and RA antibiotics, which didn't show any results, while the CTR antibodies showed a different result.

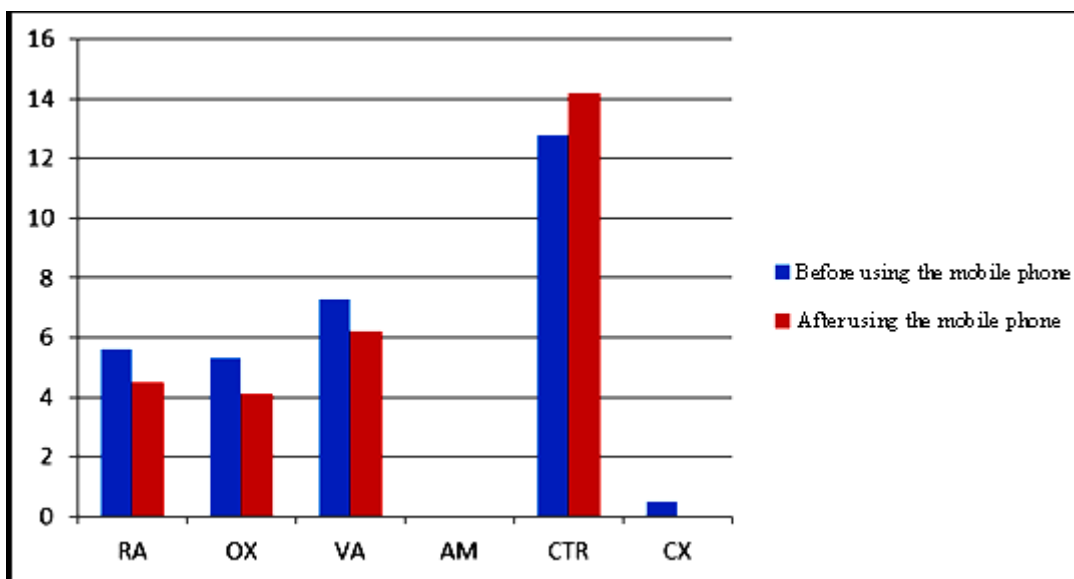


Figure 3: A comparison between the average inhibition diameters of antibiotics before and after using mobile on *Staphylococcus epidermidis* isolates.

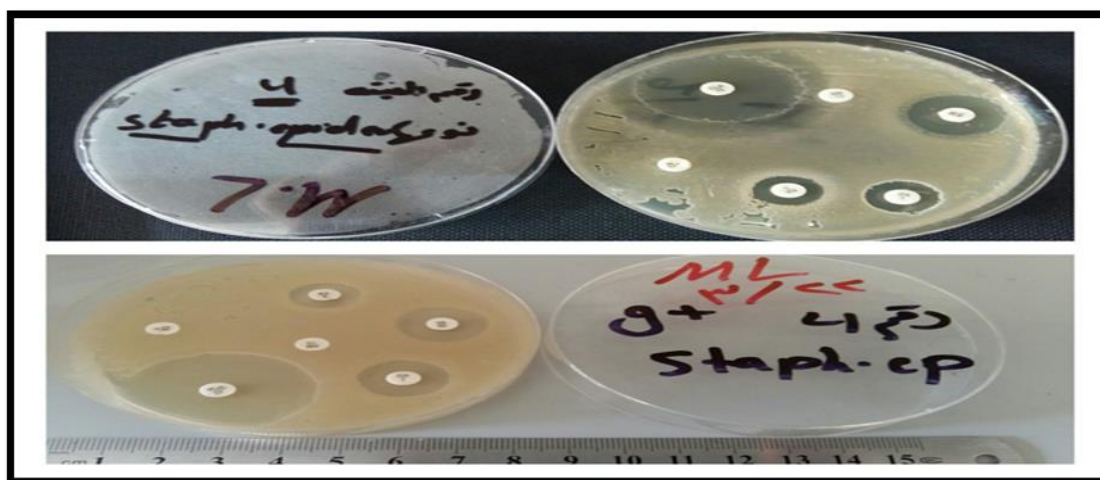


Figure 4: Inhibition diameters of antibiotics before and after using mobile on *Staphylococcus epidermidis* isolates. (A) before exposure, (B) after exposure.

The results shown in figures (5-12) show a clear effect of using mobile radiation on decreasing inhibition diameters against S.TOB antibiotics in *E. coli*, *Pseudomonas* spp., *Enterobacter* spp., and *Proteus* spp. The antibiotic AMS showed a decrease in the

average diameter of inhibition as a result of the use of mobile radiation on bacteria *Enterobacter* spp. and *Proteus* spp., as well as the decrease in the diameter of inhibition of antibiotic NA in *Pseudomonas* spp. and *E. coli*.

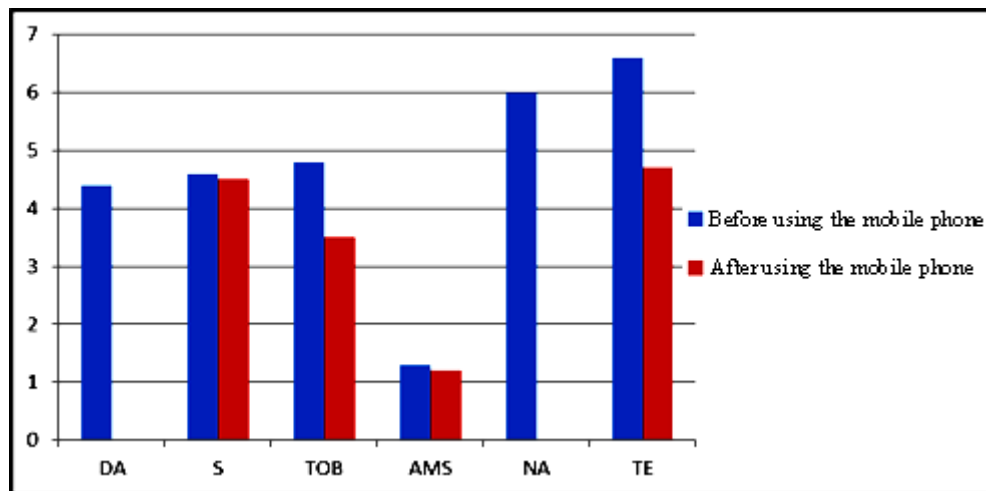


Figure 5: A comparison between the average inhibition diameters of antibiotics before and after using mobile radiation on *Enterobacter* isolates.

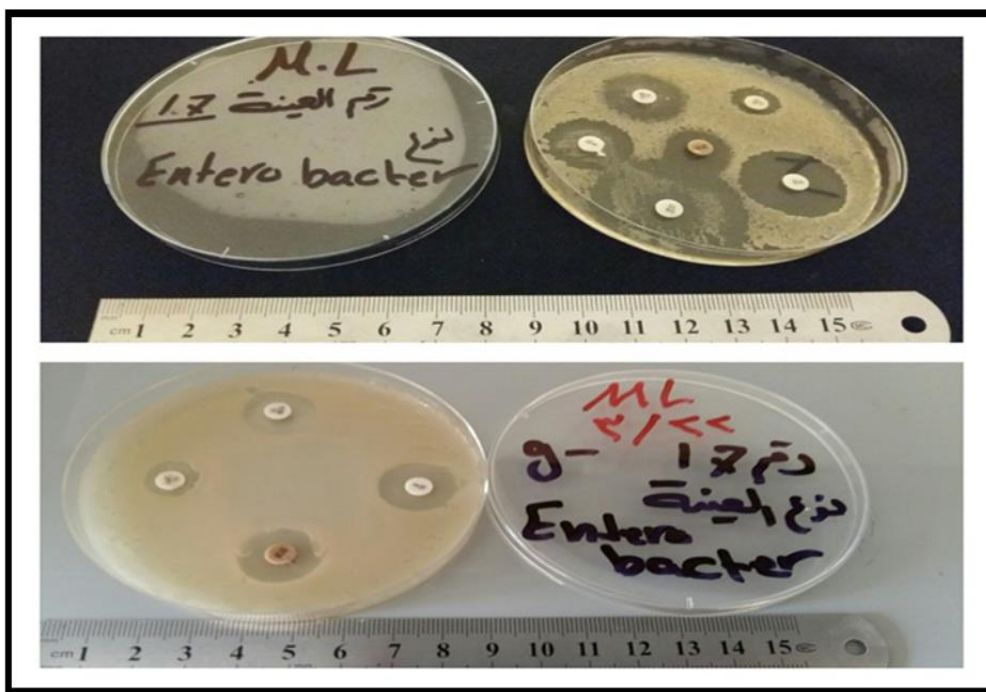


Figure 6: Inhibition diameters of antibiotics before and after using mobile on *Enterobacter* isolates (A) before exposure and (B) after exposure.

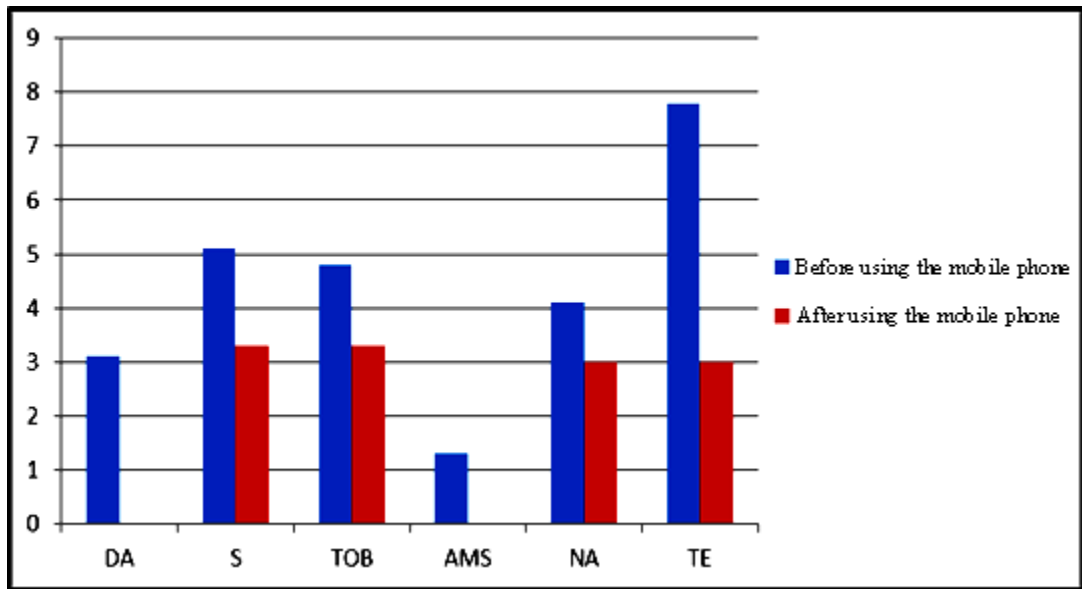


Figure 7: A comparison between the average inhibition diameters of antibiotics before and after using mobile on *Pseudomonas* isolates.

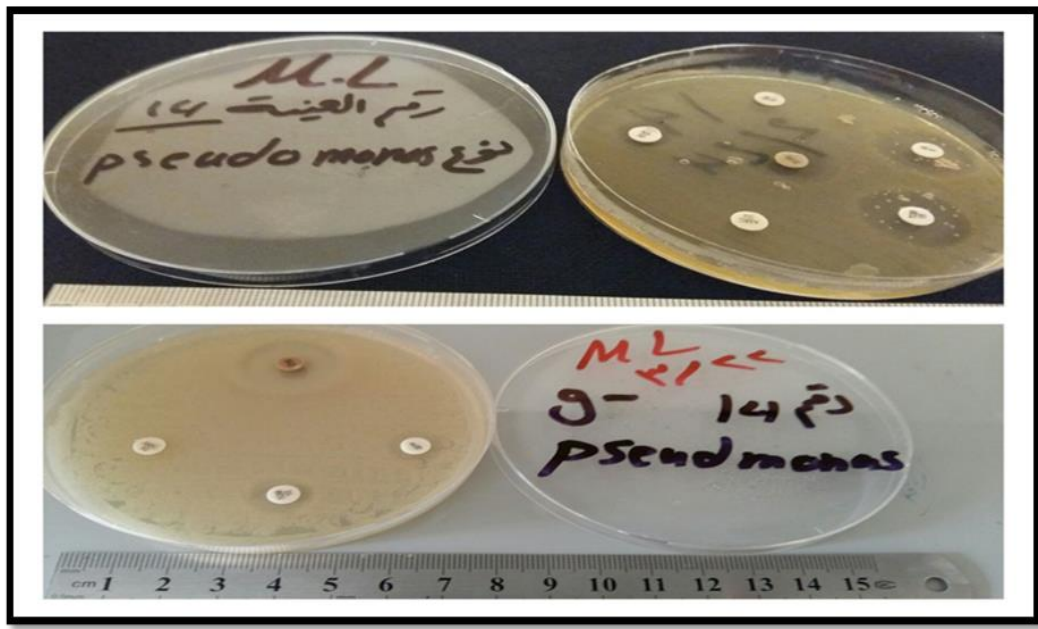


Figure 8: Inhibition diameters of antibiotics before and after using mobile on *Pseudomonas* isolates (A) before exposure, (B) after exposure



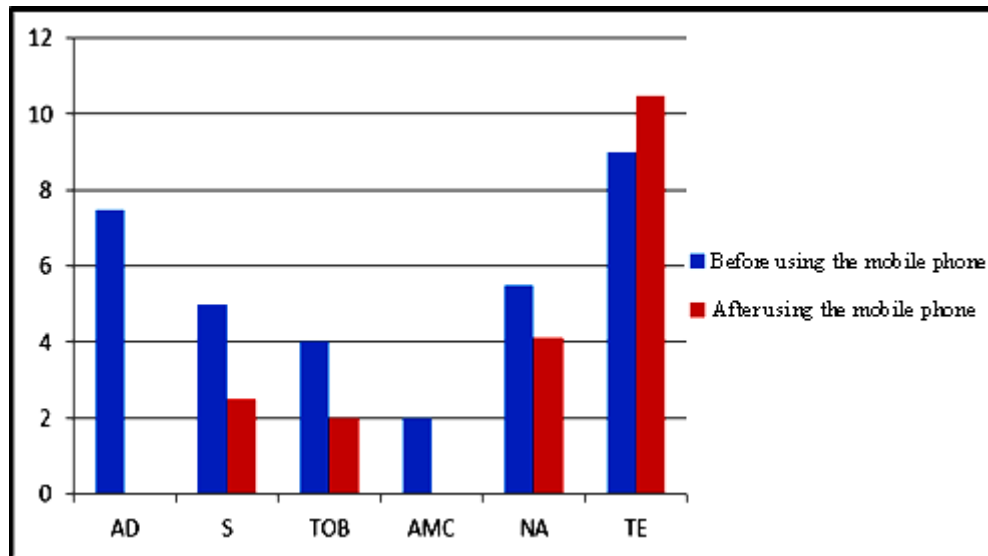


Figure 9: A comparison between the average inhibition diameters of antibiotics before and after using mobile on *E. coli* isolates.

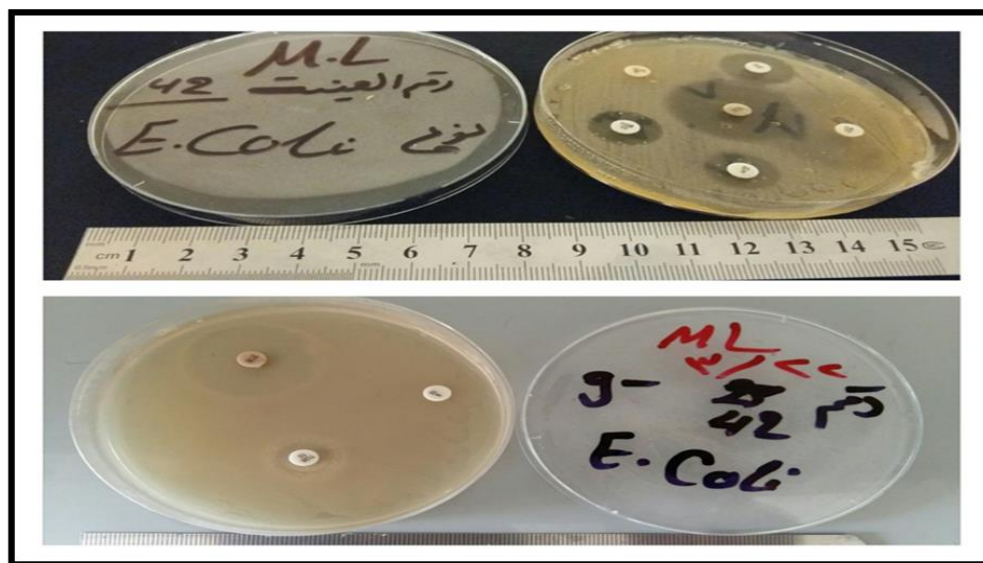


Figure 10: Inhibition diameters of antibiotics before and after using mobile on *E. coli* isolates. (A) before exposure, (B) after exposure.

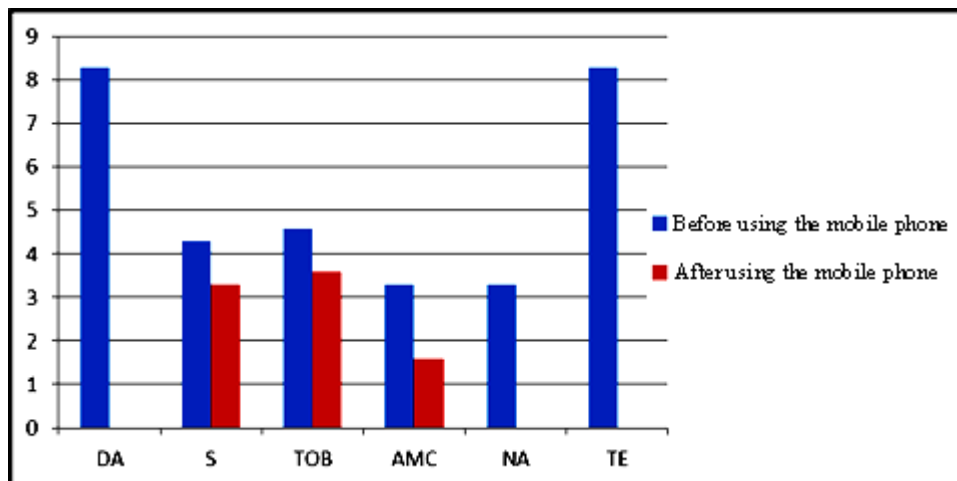


Figure 11: A comparison between the average inhibition diameters of antibiotics before and after using mobile on *Proteus* isolates.

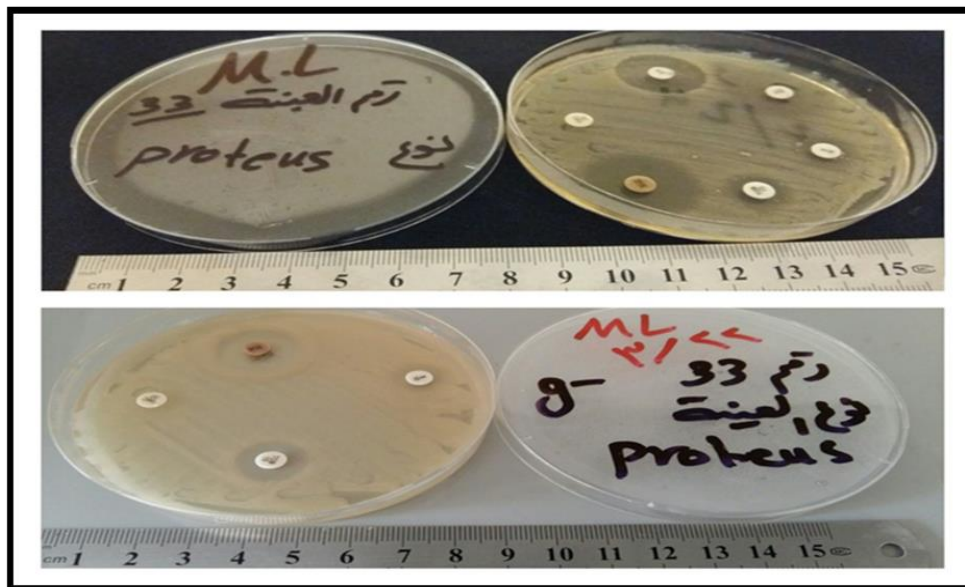


Figure 12: Inhibition diameters of antibiotics before and after using mobile on *Proteus* isolates. (A) before exposure, (B) after exposure.

As for antibiotic TE, it showed a decrease in the rate of inhibition diameter due to the use of mobile radiation on bacteria *Pseudomonas* spp. and *Enterobacter* spp., while radiation did not appear to have any effect on the rate of inhibition diameters of the antibiotics in *Proteus* spp., while the antibiotics showed an increase in the diameter of inhibition due to the use of mobile radiation on *E. coli*.

## DISCUSSION

Ear infections in adults, both acute and chronic cases, occur with high frequency. Despite this prevalence,

the etiology of such infections and the potential role of the eukaryotic mycobiome remain insufficiently understood. Our investigation focused on microbial community profiles in individuals with OM, OE, and healthy ears within the adult population. We observed that all ear types contained a combination of bacterial and fungal organisms. According to earlier studies, *Staphylococcus epidermis*, *Enterobacter*, *Pseudomonas*, *Proteus*, and *E. coli* were the most prevalent bacterial species in the healthy ear; these findings are consistent with previous studies (20).



*Staphylococcus epidermis*, *Proteus* spp., and *E. coli* were the predominant pathogens in ear infections. The significant prevalence of multidrug-resistant bacteria necessitates periodic and ongoing monitoring of antibiotic use in the research area. Further investigation is recommended to explore various types of ear infections, their etiologic agents, and potential risk factors (21). The research identified distinct bacterial species with notable levels of antibiotic resistance. For example, 45.3% of *Staphylococcus epidermis* was resistant to both ampicillin and cefoxitin, 20% of the *Enterobacter* species were resistant to amoxicillin, 17.3% of the *Pseudomonas* species were resistant to amoxicillin and clindamycin, 10% of the *E. coli* species were resistant to amoxicillin, and 6.6% of the *Proteus* species were resistant to amoxicillin and clindamycin. Comparable findings were also observed in other investigations (22).

The gender and duration of mobile phone usage among survey participants displayed statistically significant variations, indicating that men are more inclined to utilize mobile phones. These findings are consistent with the research conducted by (23). As previously observed, the study indicates a discernible contrast in the inhibition diameters of all antibiotic types employed and the bacterial species identified and isolated from the ear subsequent to exposure to specific durations of mobile radiation. In these instances, there was a reduction in inhibition diameters, indicating an escalation in bacterial resistance subsequent to mobile radiation exposure. To reduce exposure to mobile radiation, several precautions can be taken, such as keeping the phone away from the body, using the speakerphone during calls, sending text messages instead of making calls whenever possible, utilizing a landline phone when available, and turning off or putting the phone on airplane mode when not in use. Additionally, it is advised to avoid using the phone when its battery is low and to refrain from using it while it is charging due to a tenfold increase in radiation emission (23).

### Limitations

This study has a few key limitations. First, the sample size was relatively small—especially for certain groups like *E. coli* post-exposure—which may limit generalizability. Second, we did not perform genetic analysis of antibiotic resistance, so mechanisms

underlying observed changes remain speculative. Third, variation in mobile phone usage patterns, exposure duration, and environmental conditions were not strictly controlled, potentially introducing bias.

### CONCLUSION

The use of mobile phones was examined among students from both the scientific and humanities departments—male students reported longer usage than female students. *S. epidermidis* was the most commonly isolated bacterial species in the samples. The average daily mobile phone use ranged between 1 and 6 hours. Exposure to mobile phone radiation was associated with decreased inhibition zones for antibiotics RA, OX, and VA antibiotics in *S. epidermis*. Furthermore, antibiotic groups S and TOB demonstrated reduced effectiveness—evidenced by smaller inhibition zones—against *Enterobacter* spp., *Pseudomonas* spp., *Proteus* spp., and *E. coli*. These observations suggest that mobile phone radiation may negatively influence bacterial susceptibility to certain antibiotics.

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### Conflict of Interest

The authors declare that there is no conflict of interest.

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