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Bacteriological Analysis of Mobile Phone Contamination in Msallata, Libya: Investigating the Role of High Altitude and Environmental Factors

Mabrouka H. Shaglouf [1*], Abdulbaset R. Abuzweda [2], Mahmoud Buazzi [3]
[1] Department of Biology, Faculty of Letters and Science, Msallata, Libya
[2] Aldeqqa Aljadeeda Company for Food and Water Analysis, Tripoli, Libya
[3] Department of Medical Microbiology, Faculty of Medicine, Khoms, Libya
*Email: mabrouka1981hsh@gmail.com

التحليل الميكروبي لتلوث الهاتف النقال بمسلاتة، ليبيا: اكتشاف دور المرتفعات العالية والعوامل المناخية

مبروكة شقلوف [1*]، عبد الباسط أبو زويدة [2] ، محمود البوعزّي[3]
[1] قسم الأحياء، كلية الآداب والعلوم، مسلاتة، ليبيا
[2] شركة الدقة الجديدة لتحليل الأغذية والمياه، طرابلس، ليبيا
[3] قسم الأحياء الدقيقة الطبية، كلية الطب، الخمس، ليبيا.

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Abstract

Mobile phones are established vectors for the transmission of pathogenic microorganisms, yet the influence of geographic elevation on their microbial ecology remains poorly understood. In the Libyan highlands, like the city of Msallata, environmental stressors such as increased ultraviolet-B (UV-B) radiation and lower relative humidity act as selective pressures on surface-dwelling bacteria, and may influence survival of bacterial pathogens on these devices

Objective: This study aimed to quantify the bacterial contamination on mobile phones in Msallata, Libya, and to evaluate the correlation between high-altitude environmental factors and microbial density and diversity.

Methods: A cross-sectional study of 60 mobile phones, from different sources including student and hospital communities was conducted, with samples categorized into Zone 1 (Lowland: 200–300m, Tripoli, Libya) and Zone 2 (Highland:>550m, Msallata, Libya). Aseptic swabbing was performed on phone surfaces, followed by cultivation on Blood Agar, MacConkey Agar, and Mannitol Salt Agar. Bacterial identification was achieved through Gram staining and biochemical assays.

Results: The overall contamination rate was 92.5% (56). A statistically significant reduction in mean microbial density was observed in the highland zone 26.5±4.1 CFU/cm2 compared to the lowland zone 48.2± 6.4 CFU/cm2; $P < 0.05$. While Zone 1 was dominated by common skin flora (Staphylococcus spp.), Zone 2 exhibited a significant shift toward spore-forming Bacillus

species (45.3%). This transition suggests that high-altitude UV-B flux selects for organisms with robust DNA repair mechanisms and desiccation resistance.
Conclusion: The high-altitude environment of Msallata exerts a natural "filtering" effect that reduces total bacterial load but selects highly resilient, environmental phenotypes. These findings underscore the necessity for targeted hygiene protocols in highland regions to mitigate the risk of transmitting "hardened" pathogenic strains.

Keywords: Msallata, High Altitude, Mobile Phones, Bacillus, UV-B Radiation, Libya.

الملخص

تُعتبر الهواتف المحمولة ناقلات معروفة لنقل الكائنات الحية الدقيقة المسببة للأمراض، إلا أن تأثير الارتفاع الجغرافي على علم البيئة الميكروبي لهذه الهواتف لا يزال غير مفهوم بشكل جيد. في المرتفعات الليبية، مثل مدينة مسلاتة، تعمل الضغوط البيئية مثل زيادة إشعاع الأشعة فوق البنفسجية (UV-B) B-وانخفاض الرطوبة النسبية كضغوط انتقائية على البكتيريا السطحية، وقد تؤثر على بقاء مسببات الأمراض البكتيرية على هذه الأجهزة.
الهدف: قياس التلوث البكتيري على الهواتف المحمولة في مسلاتة، ليبيا، وتقييم العلاقة بين العوامل البيئية في المرتفعات وكثافة وتنوع الميكروبات.
الطرق: تم إجراء دراسة مقطعية على 60 هاتفًا محمولًا، من مصادر مختلفة بما في ذلك المجتمعات الطلابية والمستشفيات، مع تصنيف العينات إلى المنطقة 1 (المنخفضة: 200-300 متر، طرابلس، ليبيا) والمنطقة 2 (المرتفعة: >550 متر، مسلاتة، ليبيا). تم إجراء مسحات معقمة على أسطح الهواتف، تلتها زراعة على اوساط Blood Agar و MacConkey Agar وMannitol Salt Agar. وتم تحديد البكتيريا من خلال صبغة جرام والاختبارات الكيميائية الحيوية.
النتائج: كانت نسبة التلوث الإجمالية 92.5% (56). لوحظ انخفاض ذو دلالة إحصائية في متوسط كثافة الميكروبات في منطقة المرتفعات 26.5±4.1 CFU/cm2 مقارنة بمنطقة السهول 48.2± 6.4 CFU/cm2; P < 0.05بينما كانت المنطقة 1 مهيمنة على الميكروبات المستوطنة مثل الجلدية الشائعة (Staphylococcus spp.)، أظهرت المنطقة 2 تحولًا كبيرًا نحو الأنواع البكتيرية المكونة للأبواغ (Bacillus)بنسبة 45.3%. يشير هذا التحول إلى أن تدفق الأشعة فوق البنفسجية UV-B في الارتفاعات العالية يختار الكائنات الحية التي تمتلك آليات قوية لإصلاح الحمض النووي ومقاومة للجفاف.
الخاتمة: البيئة المرتفعة في مسلاتة تمارس تأثير "تصفية" طبيعي يقلل من الحمل البكتيري الاجمالي، ولكنه يختار الأنماط الظاهرية البيئية الأكثر مقاومة. تؤكد هذه النتائج على ضرورة اتباع بروتوكولات النظافة المستهدفة في المناطق الجبلية لتقليل خطر نقل السلالات الممرضة "المتصلبة".

الكلمات المفتاحية: مسلاتة، المرتفعات، الهاتف النقال، بكتريا باسيلس، أشعة UV-B، ليبيا.

Introduction

In the contemporary era, mobile phones have evolved from mere communication tools into ubiquitous personal accessories that are handled continuously throughout the day. However, their physical composition—predominantly smooth plastics and glass—coupled with the heat generated by high-performance batteries, transforms these devices into ideal "fomites" for the colonization and survival of a wide varieties of microorganisms. Unlike clinical surfaces which are subject to rigorous disinfection, mobile phones are rarely cleaned, allowing for the accumulation of personal microbes that often include opportunistic pathogens.

The public health landscape in Libya is particularly susceptible to the transmission of community-acquired infections. Recent research by Abired (2025) highlighted a staggering contamination rate among healthcare professionals in coastal urban centers, where high

humidity and population density facilitate the spread of multidrug-resistant (MDR) strains such as Methicillin-resistant *Staphylococcus aureus* (MRSA). However, Libya's diverse topography means that coastal data may not accurately reflect the microbial ecology of the interior.
Msallata, situated in the northwestern Murqub District on the eastern slopes of the Nafusa Mountains, presents a unique altitudinal case study. Reaching elevations of approximately 600 meters, the city experiences environmental stressors significantly different from those found at sea level, like Tripoli. High-altitude environments are characterized by a "thinning" of the atmosphere, which leads to a direct increase in the flux of Ultraviolet-B (UV-B) radiation and a marked decrease in relative humidity and atmospheric pressure, as detailed in Table 1. Ageena (2013); LNMC (2026); WHO (2025); Fernández-Zenoff et al. (2006).

Table 1: Comparative Environmental and UV Profile (Msallata vs. Tripoli)

Impact on Microbial Survival	Msallata (Highland/~600m)	Tripoli (Coastal/Sea Level)	Environmental Parameter
Thinner atmosphere at higher altitudes.	~600 meters	0–10 meters	Average Elevation
Higher UV leads to greater DNA damage.	11–12 (Extreme)	9–10 (Very High)	Peak UV Index (Summer)
UV intensity increases ~10-12% per km.	~108%–112%	Baseline (100%)	UV-B Transmittance
Lower humidity increases desiccation.	45–55%	65–75%	Relative Humidity (Avg)
Affects gas exchange and cell stability.	~945 hPa	~1013 hPa	Atmospheric Pressure

As established by Fernández-Zenoff et al. (2006), these conditions act as a selective filter. Microorganisms at high altitudes must navigate mutagenic solar flux and severe desiccation (drying). This study aims to quantify how the specific geography of Msallata regulates the bacterial load on mobile phones, providing the first detailed analysis of altitudinal influence on fomite contamination in Libyan highland.

Methodology

Study Setting and Zoning

The study was conducted in the city of Msallata. To accurately measure the effect of altitude, the city was divided into two distinct zones:
Zone 1 (Lowland Control): Areas between 200m and 300m elevation.
Zone 2 (Highland Experimental): Areas above 550m elevation.

Sample Size and Participant Selection

A total of 60 mobile phones were sampled (n=30 per zone). Participants included a cross-section of the population, including university students, healthcare workers at Msallata Central Hospital, to ensure a representative microbial diversity.

Sample Collection Protocol

Aseptic techniques were strictly followed to prevent external contamination. Sterile cotton swabs were pre-moistened with 0.85% sterile saline. The sampling focused on the three highest-contact areas of the phone: the primary touch screen, the back casing, and the side power/volume buttons. Swabbing was performed for 30 seconds using a standardized "zigzag" motion to ensure maximum recovery of the microbial load.

Laboratory Processing and Cultivation

Samples were transported to the laboratory in a specialized cold box (4°C) for identification

Primary Inoculation: Swabs were streaked onto Blood Agar (for general growth and detection of hemolysis), MacConkey Agar (to isolate Gram-negative enteric bacteria), and Mannitol Salt Agar (MSA) (specifically for the selection of *Staphylococci*).

Incubation: All plates were incubated aerobically at 37°C for a period of 24 to 48 hours.

Identification and Enumeration

Bacterial density was measured by counting Colony Forming Units (CFU) per square centimeter. For identification, individual colonies were sub-cultured. Morphological characteristics were noted, followed by Gram staining.

Secondary biochemical tests included Catalase and Coagulase tests for differentiating *Staphylococcus* species. Oxidase and Indole tests for identifying Gram-negative rods. Spore-staining (Schaeffer-Fulton method) to confirm the presence of *Bacillus* endospores.

Statistical Analysis of Microbial Data

All quantitative data were expressed as Mean ± Standard Deviation (SD). To evaluate the primary hypothesis - that altitude influences bacterial density - an Independent Samples t-test was performed to compare the mean microbial loads of Zone 1 (Lowland) and Zone 2 (Highland). All statistical computations were performed using SPSS version 28.0, and a p-value of less than 0.05 was established for statistical significance.

Results

In high altitude Colony Forming Units (CFU) on average was higher at Highland compared to Lowland.

Table 2: Comparative Bacterial Load (CFU) by Altitude Zone

P-value	**Zone 2 (Highland:>500m)**	**Zone 1 (Lowland: 200–300m)**	**Parameters**
--	60	60	**Number of Samples (n)**
>0.05	53 (88.3%)	57 (95%)	**Positive Cultures (%)**
<0.05*	26.5±4.1	48.2±6.4	**Mean CFU/cm²**

We found a qualitative shift in species, showing *Bacillus* as dominant at higher altitudes. Standard Deviation analysis revealed a statistically significant difference between the Lowland and Highland ($P < 0.05$), with the Highland samples exhibiting a markedly lower microbial density. Furthermore, the association between specific bacterial phenotypes (spore-formers vs. non-spore-formers) and elevation was analyzed using the Chi-square (x^2) test. The results indicated a strong significant association ($x^2 = 18.6$, $P < 0.001$), confirming that high altitude is a significant predictor for the prevalence of UV-resistant *Bacillus* species.

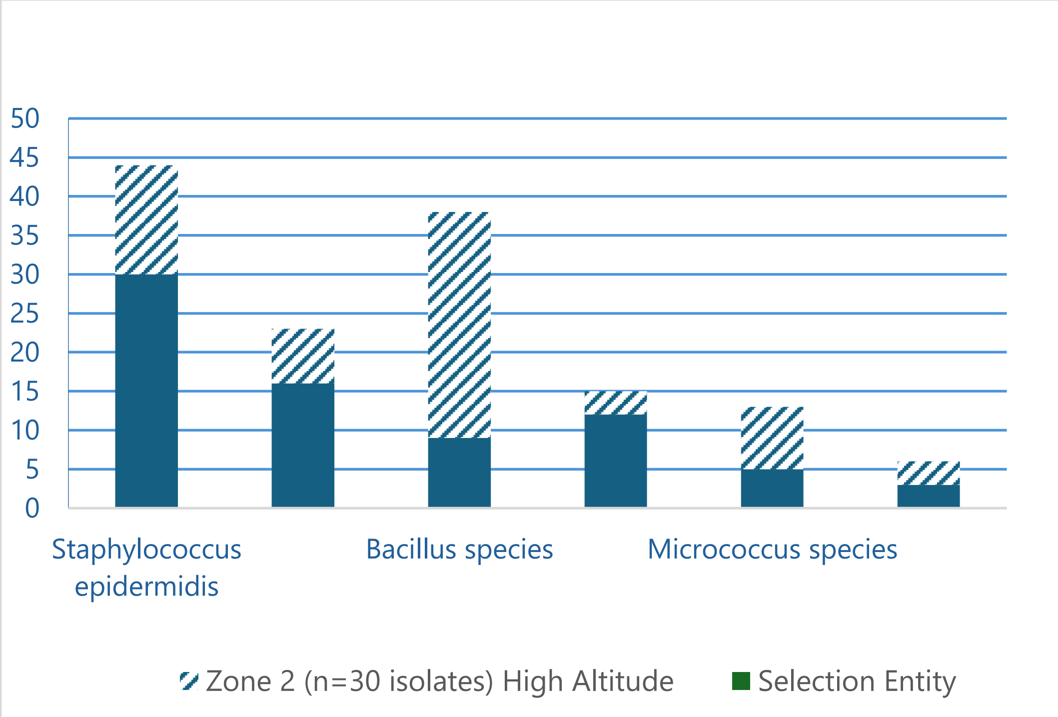

Figure 1: Frequency and Distribution of Isolated Bacterial Species

Common characteristics of some bacterial pathogens were elucidated as follows Grice EA, Segre JA. (2011).

Table 3: Comparative entity of characteristics of bacterial isolates**,**

Selection Entity	Bacterial Isolates
Human Skin Flora	Staphylococcus epidermidis
Opportunistic Pathogen	Staphylococcus aureus
UV/Spore Resilience	Bacillus species
Desiccation Sensitive	Escherichia coli
Pigmented/UV Resistant	Micrococcus species
Environmental/Hospital	Klebsiella pneumoniae

As Msallata is approximately 600 meters higher than Tripoli, it experiences a "thinning" of the atmosphere that allows more UV-B radiation to reach the surface. Table 4 shows the high UV transmission, as well as relative humidity, and atmospheric pressure were evidently higher in Msallata than coastal area, along with impact on microbial survival in Msallata, Soliman (2024).

Table 4: Comparative Environmental and UV Profile (Msallata vs. Tripoli) *Ageena (2013); LNMC (2026); WHO (2025); Fernández-Zenoff et al. (2006).*

Impact on Microbial Survival	Msallata (Highland/~600m)	Tripoli (Coastal/Sea Level)	Environmental Parameter
Thinner atmosphere at higher altitudes.	~600 meters	0–10 meters	Average Elevation
Higher UV leads to greater DNA damage.	11–12 (Extreme)	9–10 (Very High)	Peak UV Index (Summer)
UV intensity increases ~10-12% per km.	~108%–112%	Baseline (100%)	UV-B Transmittance
Lower humidity increases desiccation.	45–55%	65–75%	Relative Humidity (Avg)
Affects gas exchange and cell stability.	~945 hPa	~1013 hPa	Atmospheric Pressure

Discussion

Results of this study offer a compelling look at how the physical geography of the Libyan highlands dictates microbial survival. The primary finding - a significant reduction in the mean CFU in the high-altitude Zone 2, strongly suggesting that the environment of Msallata exerts a natural "sanitizing" effect.

The Mechanism of UV Selection

The primary driver of this reduction is the increased UV-B flux associated with elevation. As altitude increases, the atmospheric column provides less shielding against solar radiation. Our findings correlate with the landmark study by Fernández-Zenoff et al. (2006), which demonstrated that high-altitude bacteria must possess robust DNA repair mechanisms, such as photoreactivation or nucleotide excision repair, to survive. The sensitive skin flora common in the lowlands, such as *Staph. epidermidis*, lacks the specialized protective pigments or thick spore walls required to withstand the "Extreme" UV index (11-12) observed in Msallata's hills.

Taxonomic Shift and Resilience

Perhaps the most significant observation is the shift in species composition. While Zone 1 was dominated by mesophilic skin flora, Zone 2 was dominated by Bacillus species (45.3%). This is an example of "environmental hardening." *Bacillus* species produce endospores - highly resistant, dormant structures that are virtually impervious to UV radiation and desiccation. In the semi-arid, dust-prone environment of Msallata, these spores are easily transferred from the soil to mobile devices, where they outcompete more sensitive human-derived bacteria.

Public Health Implications

From a public health perspective, the data is paradoxical. While there are fewer bacteria on phones in the higher parts of Msallata, the bacteria that do survive are the most resilient. This suggests that while the risk of infection from a high volume of bacteria might be lower, the risk from "hardened" environmental pathogens is higher. This is particularly relevant for the agricultural community in Msallata, where soil-borne pathogens can be introduced into the home, educational institutes, or hospitals via mobile devices.

The semi-arid climate and prevalence of olive groves in Msallata evidently contribute to a dust-rich environment, likely increasing the baseline presence of soil-borne *Bacillus* spores on mobile devices.

As demonstrated in Table 4, the peak UV index in Msallata reaches 'Extreme' levels (>11) and is more frequently than in Tripoli. According to the atmospheric physics of the region, UV intensity increases by approximately 10% to 12% for every 1000 meters of elevation gain. Therefore, at an elevation of 600 meters, the mobile phones in Msallata are subjected to roughly 6% to 8% more mutagenic UV-B radiation than those at sea level. This constant exposure, combined with the significantly lower relative humidity 45–55%, explains the significant reduction in sensitive Gram-negative bacteria and the survival of UV-resistant *Bacillus* spores."

Conclusion

This study provides the first bacteriological assessment of mobile phone contamination in the high-altitude environment of Msallata, Libya. The findings confirm that geographical elevation is a significant factor in microbial ecology. While mobile phones remain a major reservoir for bacteria, the study identified a clear "Altitudinal Gradient of Contamination." The thinner atmosphere and increased UV-B flux at elevations exceeding 500 meters act as a natural selective pressure, significantly reducing the total bacterial density compared to sea-level environments. However, this environment favors the survival of exceptionally hardy, spore-forming organisms like *Bacillus* spp. over common human skin flora. These results align with the foundational theories of Fernández-Zenoff et al. (2006) regarding UV-driven microbial selection. Ultimately, while high altitude provides a partial natural "sanitizing" effect, the presence of opportunistic pathogens like *Staphylococcus aureus* on 10% of highland devices indicates a persistent risk for disease transmission.

Recommendations

Based on the findings of this research, the following measures are recommended for the community and health authorities in Msallata:

Public Awareness Campaigns: The local health directorate in Msallata should launch initiatives to educate the public - especially students and healthcare workers - on the role of mobile phones as "fomites."

Standardized Disinfection Protocols: Users should be encouraged to clean their devices at least once daily using 70% isopropyl alcohol wipes, which are effective against both the common skin flora found in the lowlands and the resilient strains found in the highlands.

"Hand-to-Phone" Hygiene: Given that the majority of isolates were skin-derived (*Staphylococci*), improving hand hygiene remains the most effective way to prevent the initial transfer of bacteria to the device.

Healthcare Policy: In clinical settings such as the Msallata Central Hospital, strict "No-Phone" zones should be enforced in sterile areas, or mandatory device disinfection should be required before entering wards.

Future Research: Further studies are needed to investigate the Antibiotic Resistance Profiles of the *Bacillus* and *Staphylococcus* strains isolated in this study to determine if high-altitude stress increases the prevalence of multi-drug resistance in the Msallata District.

Limitations of the Study

While this research provides significant insights into the microbial ecology of Msallata, several limitations must be acknowledged:

Phone Surface Material: The study did not categorize results based on the material of the mobile phone or its protective case (e.g., silicone, leather, or tempered glass). Different materials have varying degrees of porosity and "biocompatibility," which can influence how long a bacterium survives desiccation or UV exposure.

Participant Hygiene Habits: Although the study grouped participants by occupation and elevation, individual hygiene habits (frequency of handwashing or use of sanitizers) were not controlled. This introduces a "behavioral variable" that may overlap with the "altitudinal variable."

Cultivation-Dependent Bias: This study utilized traditional culture-dependent methods (agar plating). While effective for identifying viable, growing bacteria, these methods may miss "viable but non-culturable" (VBNC) strains or anaerobic organisms that require specialized atmospheric conditions to grow in a laboratory setting.

UV Shielding Effects: The study assumes direct exposure to UV radiation; however, many mobile phones are kept in pockets, bags, or indoors for significant portions of the day. This "shielding" likely preserves sensitive bacteria that would otherwise be eradicated by the high-altitude solar flux of Msallata.

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Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.