

Investigation of the bacterial flora on the cellphones of medical staff in the pediatric-neonatology department of Mecheria-Algeria

Sidi Mohammed Lahbib Seddiki^{1,2}, Mohammed Reda Mediouni^{1,3}, Wafa Benkhedda¹, Meghnia Hafdi¹

¹ Laboratory for Sustainable Management of Natural Resources in Arid and Semi-Arid Areas, University Center of Naama, Naama, Algeria

² Antifungal Antibiotic: Physico-Chemical Synthesis and Biological Activity Laboratory, University of Tlemcen, Naama, Algeria

³ Applied Genetics in Agriculture, Ecology and Public Health Laboratory, University of Tlemcen, Naama, Algeria

Corresponding author: Sidi Mohammed Lahbib Seddiki (seddiki@cuniv-naama.dz)

Summary

The use of cell phones during medical care is a concern due to the transmission of pathogenic bacteria between medical staff and patients. This habit can lead to treatment errors, resulting in high mortality and additional therapeutic costs. The study aims to evaluate the infectious risk associated with using cell phones in the pediatric-neonatology department in Mecheria-Algeria, focusing on identifying bacteria that contaminate cell phone surfaces, the formation of biofilms and their resistance to antibiotics. The results showed that the microbial burden on cell phone surfaces ranged from 35 ± 5 to $28 \times 10^4 \pm 120$ CFU/phone surface (CFU/PS). Gram-positive strains were predominant, including *Staphylococcus xylosus* and *Bacillus* sp. However, Gram-negative bacteria such as *Aeromonas hydrophila*, *Micrococcus* sp., *Pseudomonas luteola* and *Sphingomonas paucimobilis* were also isolated. The isolated bacteria showed complete resistance to Ceftazidime, while tetracycline and ciprofloxacin appeared effective against these isolates. The ability to form microbial biofilms was one of the characteristics observed in clinical isolates from the pediatric neonatology department, alongside isolates with hydrophobicity greater than 50%. However, most strains showed strong auto-aggregation at $T = 0$ min to $T = 90$ min, suggesting that initial incubation periods allowed for high auto-aggregation potential.

Key words: Bacteria, cellphones, medical staff, infectious risks



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Introduction

Healthcare professionals frequently highlight the transmission of germs between individuals in hospitals. Microorganisms are transferred from the environment to people and vice versa, as well as between patients and medical staff (Di Muzio et al. 2016; Di Simone et al. 2016). On the other hand, the mobile phone has become an indispensable tool in today's social and professional life, allowing much faster communication and more efficient exchanges between individuals. Personal mobile phones, used inside and outside hospitals, can cause undesirable repercussions within these care structures when utilized by medical staff during their activities (Akinyemi et al. 2009). In actuality, using a cell phone

is a worrying habit with harmful consequences for patients since it can distract the attention of medical staff, hence treatment errors (Sepehri et al. 2009).

Furthermore, multi-resistant bacteria that stick to mobile phone surfaces can cause significant infections, resulting in high mortality and additional therapeutic costs (Ustun and Cihangiroglu 2012). During each call, mobile phones come into close contact with highly contaminated human body parts, including hands, mouth, nose, and ears. As a result, microorganisms contaminate the device, adhere to its surface, and initiate the formation of a complex structure called biofilm (Brady et al. 2011; Ustun and Cihangiroglu 2012). A biofilm is an organized population of microbes adhering to a surface and enclosed in a self-produced matrix. In other words, a biofilm is a population of microorganisms that have formed a sophisticated social structure and live collectively (Costerton et al. 1978, 1995). However, biofilms impact public health. In 1999, Costerton and colleagues attributed the infectious nature of biofilms. The matrix constitutes a protective barrier against host defence mechanisms and external threats, such as antibiotics (Irie et al. 2012; Bjarnsholt 2013; Lebeaux et al. 2014; Gupta et al. 2016). A pediatric surgery service has been established in the Mecheria Hospital as part of a program designed exclusively to care for children in this remote area of Algeria. Because they can contribute to the spread of microorganisms, Olsen et al. (2021), who conducted a study on the use of mobile phones in pediatric services, consider these devices Trojan horses. The main objective of this study revolves around this subject. It focuses on evaluating the sessile bacterial flora that adheres to mobile phones of the medical staff of the pediatric service of Mecheria-Algeria and its potential pathogen.

Material and methods

Sampling

The samples were collected at Mecheria Hospital Pediatrics and Neonatology department. This service is the only one in this remote region of southern Algeria. It has two sections: the neonatal part, which is reserved for babies aged one day to two months, and the pediatric part – for children aged one month to five years. Five specialist doctors and twenty-two nurses perform therapeutic and medical acts in this service.

The samples were collected from cell phones in February 2024. In parallel with the sampling, each participant was given a questionnaire to fill out. The purpose of the questionnaire was to collect information on how often they wash their hands after using their phones, where they use them, whether they wear gloves, how much they use their phones at work, and whether or not the staff cleans their phones and, if so, how. The World Health Organization (WHO 2009) and previous technical sheets (Boucherit-Antmani et al. 2011; Olsen et al. 2021; Amara et al. 2023) were a reference for developing this questionnaire.

We collected the samples using sterile swabs, first moistening them with sterile physiological water and then rubbing them against the surface of the phones by making back-and-forth movements. The swabs were quickly placed into tubes containing 5 ml of sterile physiological water, which were labelled before being transported to the microbiology laboratory for analysis. The sampling was carried out, ensuring maximum asepsis.

Bacterial count

The quantification of bacterial presence on cell phones of the medical staff at Mecheria Hospital was determined using the spread plate method. This was achieved by performing a series of dilutions from the tubes taken from the sample. Afterwards, 100 μ L were evenly spread by a rake on nutrient agar (pH 7) previously poured into the Petri dishes and incubated at 37 °C for 24–48 hours. The amount of bacterial particles that contaminated the surfaces of the examined mobile phones corresponds to the number of colony-forming units per surface of the phone (CFU/PS). Each test was performed three times. Results were expressed as mean \pm standard error.

Isolation and identification

Many aspects of the colonies, such as colour, size, and form, were considered when selecting the bacterial isolates. Isolation was used to separate the different strains from the suspension from each sample. A series of successive sub-cultures between liquid and solid media was carried out for this purpose. Slanted nutrient agars in tubes were inoculated to preserve pure bacterial strains. The isolates were kept cold at 4 °C.

We employed fresh-form microscopic analysis and Gram staining to evaluate the isolates' morphology, motility, and grouping pattern and categorize them as Gram-positive or Gram-negative. API galleries (API 20E, API 20NE, API Staph, API 50 CHB, bioMerieux) were used for the biochemical identification of selected isolates. They were inoculated and then incubated at 37 °C. We compared our results with those in the leaflet provided with the API galleries, which allowed the identification of the isolates.

Antimicrobial susceptibility testing

We tested the sensitivity of the isolated bacteria against six antibiotics chosen according to their frequency of use in the pediatric-neonatology department of Mecheria Hospital. It was, therefore, important to verify the effectiveness of their antibacterial properties. The method we used is that of the European Committee for Antibiogram (EUCAST 2020), with some modifications. It is based on the diffusion of antibiotics from the discs into the solid medium on which the isolates were inoculated.

Antibiotics discs used in the antibiogram test were Amoxicillin (AML, 30 μ g), Ceftazidime (CAZ, 30 μ g), Tetracycline (TE, 30 μ g), Gentamicin (CN, 10 μ g), Erythromycin (E, 15 μ g) and Ciprofloxacin (CIP, 5 μ g). We measured the diameters of the inhibition zones in mm, and the results were interpreted according to the EUCAST recommendations (EUCAST 2020).

Assessment of biofilm formation

The methodology used is based on the qualitative approach of O'Toole (2011). For each isolate, an 18-hour young culture was suspended in nutrient broth at 10⁸ cells/mL concentration. 300 μ L of each bacterial suspension was inoculated into the wells of a sterile 96-well microplate. A control test was performed

by introducing only sterile nutrient broth into one well to serve as a negative control. All tests were performed in triplicate.

Following a 24-hour incubation period at 37 °C for the microplates, the bacterial suspension supernatant was extracted from the wells and subjected to a tap water wash to eliminate any planktonic bacteria or cells not adhering to the wells' walls. The supposed biofilms formed in the wells were fixed by adding 300 µL of ethanol for an action time of 15 min. After the microplate draining procedure, 320 µL of crystal violet solution (0.1%, w/v) was added to the wells and left to act for 40 minutes. After removing any leftover violet pigment, the wells were washed with tap water and drained. The wells were filled with 300 µL of 33% acetic acid and allowed to act for 20 min. Next, 250 µL of bacterial suspension was transferred to the wells of a fresh microplate.

Using a microplate reader (OPTIC IVYMEN SYSTEM 2100C), the absorbance was evaluated at a wavelength of 570 nm. The absorbance values indicated the amount of crystal violet retained, which reflects the biomass of bacterial biofilms formed on the walls of the wells. The absorbance results in each well were compared with the results of the negative control test, and the critical values of Stepanović et al. (2007) were used to determine the biofilm-forming potential of each strain. Each test was performed in triplicate.

To obtain additional data, we performed a fluorescence microscope analysis (Euromex iScope, IS.3152- PLi/3 to evaluate bacterial adhesion to shock-resistant coatings of cell phones. We cut 10 mm diameter discs from these protective coatings and then rinsed them with sterile distilled water. They were then fixed by a glutaraldehyde suspension (2.5%, w/v) before their observation. Sterile discs of the same nature were prepared to serve as a negative control. We used Green (520 nm) and blue (475 nm) fluorescence filters without staining the samples.

Auto-aggregation test

A test was performed to further understand the evolution of auto-aggregation over time according to the method described by Del Re et al. (2000). Auto-aggregation is macroscopically observed in pure culture as a bacterial clump forming at the bottom of the culture tubes (Nwoko and Okeke 2021).

A few colonies from young 18-hour cultures were placed in conical tubes containing 5 mL of phosphate-buffered saline (PBS, 10 mM, pH 7.4). The suspension was centrifuged at 4500 g for 15 minutes at 4 °C. The supernatant was removed, and the pellet was washed twice with PBS. The initial absorbance (A_0) was then adjusted to $A_0 = 1$ at a wavelength of 580 nm using a spectrophotometer (WPA-BIOWAVE II+). The cell suspension was then vortexed for 10 seconds and left at room temperature in the laboratory (22 °C). Time intervals were used to measure the absorbance; initially at $t_0 = 0$ min, then at $t_1 = 30$ min, $t_2 = 60$ min, $t_3 = 90$ min and finally at $t_4 = 24$ hours. We took 0.5 mL from the upper edge of the suspension to measure the new absorbance (A). The percentage of auto-aggregation was calculated using the following formula: % auto-aggregation = $(A_0 - A) \times 100$.

Hydrophobicity assessment

The method of Krepsky et al. (2003) was followed to evaluate this characteristic. From a young culture (18 hours) previously inoculated on nutrient agar,

a few colonies were suspended in 4 mL of PBS buffer, and the concentration was adjusted to 3×10^8 cells/mL. After an incubation period of 10 minutes at 37 °C in a water bath, 400 µL of hexane was added, and the mixture was vortexed for one minute. The whole was left at room temperature (22 °C) for 15 min, which was necessary to achieve complete separation between the organic and aqueous phases. The absorbance of the aqueous phase was measured using a spectrum device (WPA-biowave II+) at 570 nm after its recovery. The following formula [% adhesion = $(A_0 - A) \times 100$] provides the solvent adhesion rate, which measures the cells' hydrophobicity, A_0 represents the absorbance of the control test, and A represents the absorbance of the sample.

The microbial surfaces were classified as hydrophobic if the bacterial adhesion rate to the solvent was greater than 50% and relatively hydrophobic if the rate was between 20% and 50% (Krepsky et al. 2003). Finally, the microbial surface was considered non-hydrophobic if the rate was less than 20%.

All tests were performed in triplicate. The results were expressed as mean \pm SE (standard error). The results were subjected to a descriptive statistical analysis using PAST software, version 4.03.

Results and discussion

Sampling

We obtained samples from the cell phone covers of twenty-five medical staff members in the pediatric-neonatology department of Mecheria Hospital. This staff included five doctors (two men and three women) and three male and seventeen female nurses. All medical staff members acknowledged owning and frequently using a cell phone. They also mentioned using commercial wipes or surgical alcohol to clean their devices, a precaution against contamination dating back to the COVID-19 pandemic. Paradoxically, one-third of them reported not wearing gloves while working.

According to a recent study, pediatric hospital staff often use cell phones in hospital restrooms. This practice can result in nosocomial infections, especially since only a minority of staff undertake proper disinfection (Olsen et al. 2021). Badr et al. (2012) highlighted that mobile phones in clinically sensitive hospital wards can cause transmission of healthcare-associated infections. Also, bacteria can survive for extended periods on smartphone surfaces (Maurici et al. 2023). In addition, Ulger et al. (2009) showed that bacteria recovered from health personnel's cell phones were similar to those populating their hands. Kumar et al. (2021) also emphasized that proper hand washing is vital.

Bacterial count

The microbial load varied among the different devices under investigation. The load on the cell phones of the medical staff at Mecheria Hospital is illustrated in Fig. 1.

According to the data obtained (Fig. 1), all phones examined were contaminated with at least one microbial agent. Simmonds et al. (2020) also found that

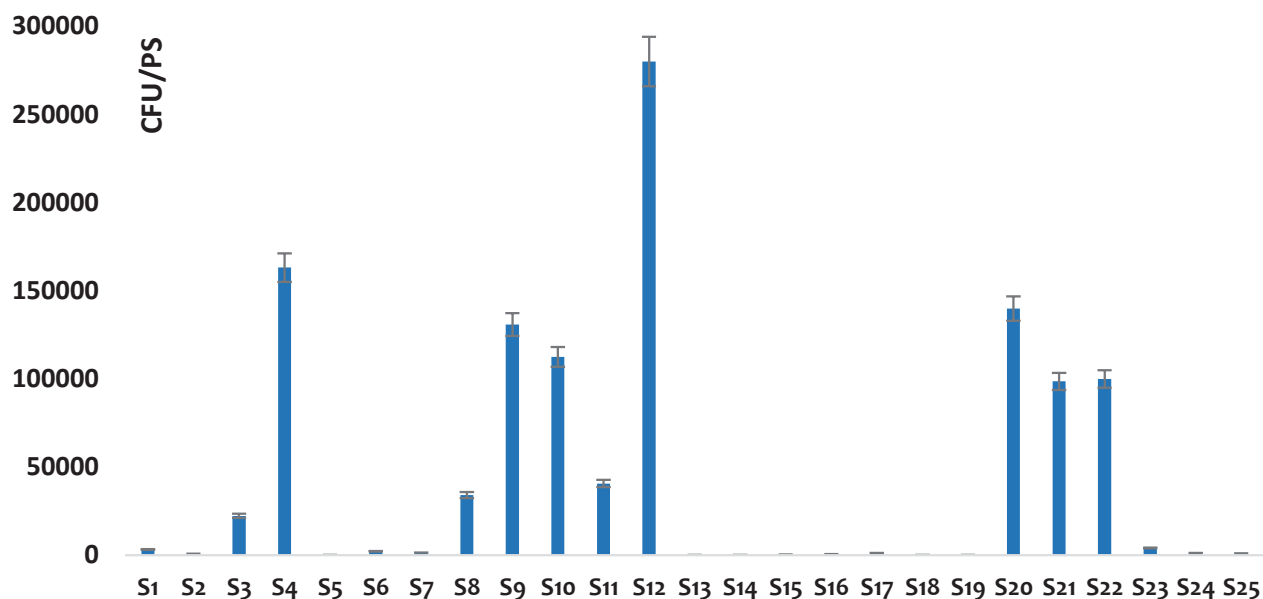


Figure 1. Microbial load distribution on medical staff cell phones. S1-S25: samples.

all hospital staff mobile phones were contaminated with potential pathogens. This result is comparable to that reported by Ustun and Cihangiroglu (2012). In contrast, Gholamreza et al. (2009) found a contamination rate of 32% in health personnel's cell phones.

Two female nurses' cell phone surfaces showed at least 35 ± 5 CFU/PS (S13) and a maximum of $28 \times 10^4 \pm 120$ CFU/PS (S12). The physicians' mobile phones had a median microbial load of 350 CFU/PS. The maximum microbial load was found on a female physician's phone (S3) with $23 \times 10^3 \pm 235$ CFU/PS, while the minimum load was 805 ± 16 CFU/PS (S2).

However, the data collected indicated that the microbial load on the surface of doctors' cell phones was lower than that of nurses. These variable loads can be partly explained by nurses performing more care acts than doctors. In addition, significant variability in the microbial load was observed among female medical staff. When taking into account the gender factor, a statistically significant difference ($P = 0.019$) was highlighted between women and men.

In this context, some research has suggested that the female gender probably plays a role in bacterial contamination of smartphones because women place them in their bags, which is conducive to bacterial growth (Bakunas-Kenneley and Madigan 2009; Bhoonderowa et al. 2014). Overall, the presence of more than 5 CFU/cm² on a surface that may come into contact with the hands suggests that the patient may be at increased risk of infection (Dancer 2004).

On the other hand, regular cleaning of cellphone surfaces is recommended (Kuriyama et al. 2021). However, despite using surgical alcohol to clean cell phones, it is important to note that it has not been able to eradicate bacterial germs from their surfaces completely. This may be the case on certain surfaces where the adhesion of organic materials is strengthened and consolidated by alcohol solutions (Bostwick et al. 1994; Moelans 2011). In addition, Ulger's team reported in 2009 that there are no recommendations regarding the use and decontamination of phones in hospital settings.

Isolation and identification

The bacterial cultures isolated from the cell phones of medical staff, particularly nurses, were more diverse than those of physicians, suggesting that the surfaces of their devices were contaminated with a broader range of bacterial species.

The microbiological results revealed different morphologies, of which fifty (50) bacterial strains were isolated from the different mobile phones studied. The results highlighted the dominance of Gram-positive bacteria (84%), including cocci forms, diplococci, tetrads, chain bacilli and sporadic forms (Fig. 2).

There is a serious risk to the public's health when germs are found on medical professionals' cell phones (Alsharedeh et al. 2023). Indeed, Lee et al. (2013) indicated in their report that cell phones used by healthcare professionals pose a significant risk factor for contamination by potentially pathogenic bacteria.

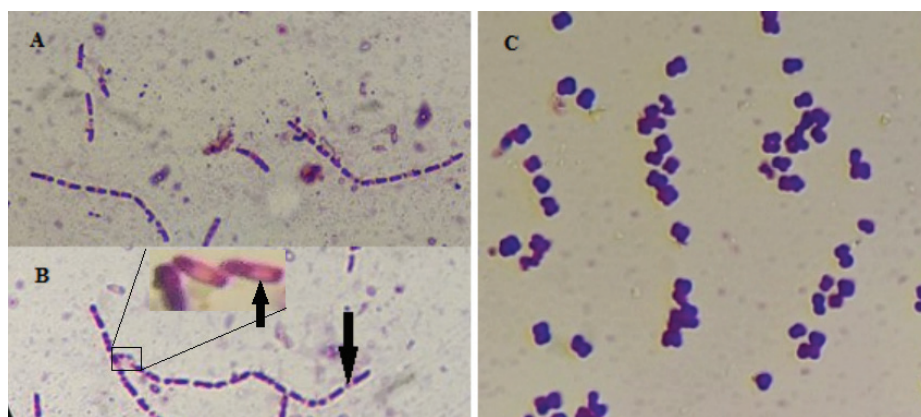


Figure 2. Microscopic observation of bacterial strains after Gram staining. **A, B.** Gram-positive bacilli (*Bacillus* sp.); **C.** Gram-positive cocci (*Micrococcus* sp.). Arrows indicate the sporadic forms ($\times 1000$ at immersion).

Biochemical tests (API galleries) revealed eight species from the fifty isolated strains. These were *Enterobacter sakazakii* (5), *Micrococcus* sp. (14), *Staphylococcus xylosum* (7), *Pseudomonas luteola* (4), *Bacillus* sp. (12), *Aeromonas hydrophila* (5), *Pantoea* sp. (1), and *Sphingomonas paucimobilis* (2).

It is important to highlight three combinations of species isolated from seven different cell phones. *Micrococcus* sp. and *Aeromonas hydrophila* (S3, S10, S21, S22), *Micrococcus* sp. and *Bacillus* sp. (S11, S20), and *Enterobacter sakazakii* and *Staphylococcus xylosum* (S9).

Compared to this study, Bhardwaj et al. (2020) isolated similar species from cell phones used in hospital settings. In addition, the study by Kuriyama et al. (2021) revealed that cell phone contamination was dominated by Gram-positive bacteria, especially *Bacillus* and *Staphylococcus* species. According to Gómez-Gonzales et al. (2023), more than 90% of the cell phones used showed bacterial growth dominated by Gram-positive bacteria, particularly *Staphylococcus* sp.

Besides that, along with methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant *Enterococcus*, Simmonds et al. (2020) highlighted the dominance of *Bacillus* sp. on cell phone surfaces. In 2017, Katsuse et al. revealed genetic similarities between strains isolated from cell phones and staff hands.

On the other hand, *Sphingomonas paucimobilis*, a Gram-negative bacterium formerly known as *Pseudomonas paucimobilis*, is commonly present in the

environment and is frequently isolated from community and hospital infections, especially medical devices (Lugito et al. 2016; Göker et al. 2017; Makanéra et al. 2017; Tuncer 2017).

Antimicrobial susceptibility testing

The results showed zones of inhibition surrounding the antibiotic disks. These zones varied in diameter depending on the antibiotic and bacterial strain (Fig. 3).

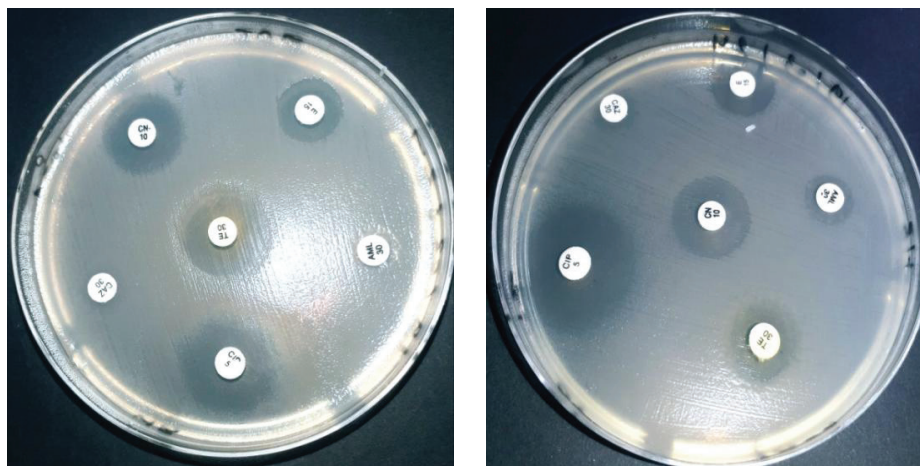


Figure 3. Antibiogram test. Appearance of inhibition zones around antibiotic disks against *Bacillus* sp.

According to EUCAST (2020) guidelines, the isolates showed variable sensitivity to the antibiotics tested. All the bacterial strains showed high sensitivity to ciprofloxacin, erythromycin, gentamicin and tetracycline, suggesting their efficacy. Elhamzaoui et al. (2009) also highlighted the antibacterial properties of these antibiotics, particularly gentamicin. In addition, using a cell phone with a touch screen is a factor associated with the presence of antibiotic-resistant bacteria on its surface, with about one in five strains isolated being resistant to three antibiotics (Gómez-Gonzales et al. 2023).

Except for *Aeromonas hydrophila*, all the strains demonstrated resistance to Ceftazidime and intermediate susceptibility to amoxicillin, suggesting the antimicrobial ineffectiveness of Ceftazidime. On the other hand, *Sphingomonas paucimobilis*, which was resistant to Ceftazidime, was inhibited by tetracycline. This finding is consistent with the observations of Makanéra et al. (2018), who stated that this species exhibits resistance to amoxicillin, gentamicin, and Ceftazidime. In contrast, the results of this study indicated that this species was sensitive to gentamicin, which contradicts their conclusions.

Assessment of biofilm formation

According to Roux and Ghigo (2006), the ability of a bacterium to form a biofilm is often associated with its virulence. Visual observation of the crystal violet test revealed that all isolates possessed this potential (Fig. 4). Based on this figure, it was possible to observe variations in the purple colour intensity among the several microplate wells, indicating that the isolates had varying biofilm formation abilities.

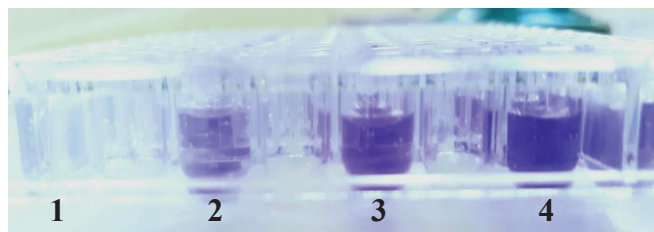


Figure 4. Results of the naked-eye assessment of biofilm formation in microplate wells. 1. Negative control test. 2, 3 and 4. Progressively positive results (weak to strong).

According to the results of the absorption measurement, seventeen (17) strains demonstrated a high potential for biofilm formation. A close number of strains (18) formed these structures weakly, while 15 strains demonstrated moderate potential (Fig. 5). These findings suggest that all the clinical isolates from the pediatric and neonatology departments could form biofilms, although their expression levels varied. On the other hand, it is worth noting that the absorbance measurement recorded a minimum median in *Staphylococcus xylosum* (0.245) and a maximum in *Shingomonas paucimobilis* (0.507).

Donlan et al. (2002) consider biofilms as reservoirs of bacterial species and survival. Bacteria prefer sessile life on a support (Nagant 2013). A hospital environment is conducive to spreading pathogens and forming biofilms on the surfaces of medical staff's cell phones (Hélio et al. 2022). In this regard, Alsharedeh et al. (2023) found that *Bacillus* and *Staphylococcus* species can form biofilms on the surface of such devices. *Pseudomonas* spp. can also form a biofilm on glass surfaces after 72 hours of incubation (Urooj et al. 2023).

The study of Olsen et al. (2020, 2021) revealed that the cell phones of pediatric hospital staff were rarely cleaned and frequently used in the toilet, leading to nosocomial consequences. Under favourable conditions, bacteria adhere and maintain themselves on a surface, form biofilms and then express their virulence (Roux and Ghigo 2006). These microbial structures mainly affect people with weakened immunity, such as children (Tasse et al. 2016).

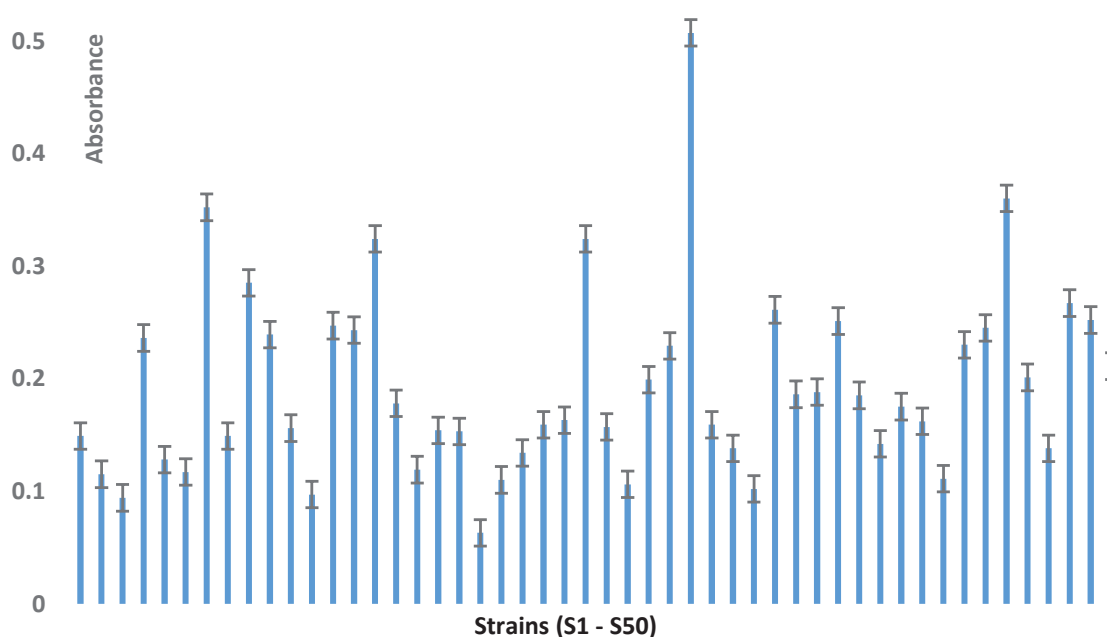


Figure 5. Histogram showing levels of biofilm formation in isolates based on their potential.

Furthermore, fluorescence microscopic observation showed extensive microbial structures on the walls of the discs of the protective coatings of cell-phones (Fig. 6). Compared to negative control tests, the emitted green light highlighted a superimposed and stratified topography. Under red light, microbiological forms were visible, and the microbial structures occupied the whole surface of the discs. These results suggest that the protective coatings of surfaces support the formation of biofilms.

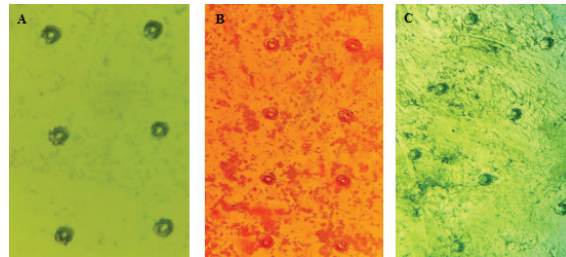


Figure 6. Cell phone protective covering discs observed under a fluorescence microscope. **A.** Negative control; **B, C.** Bacterial adhesion on the disc's surface, under red and green emitted lights, respectively (x 400).

A fluorescence microscope is a device that allows the examination of different parts of a sample according to the fluorescence emission properties of its surface (Hattori et al. 2012). However, it is essential to note that the surfaces of the cell phone protective coating discs have a rough texture. The figure illustrates spherical, button-like structures. Some studies suggest that the rougher the surface, the greater its colonization by bacteria (Donlan and Costerton 2002; Ganesan et al. 2022). In addition, the nature and properties of support surfaces influence bacterial adhesion and biofilm formation (Baillif et al. 2010; Seddiki 2021).

Auto-aggregation

Microorganisms often aggregate and group together to form bacterial communities. This process of recruiting planktonic cells is not a step in biofilm development but frequently occurs before it (Trunk et al. 2018; Seddiki 2021). According to the results of this study, the bacterial solutions became clearer over time (Fig. 7), which validates the positivity of the test (Del Re et al. 2000).

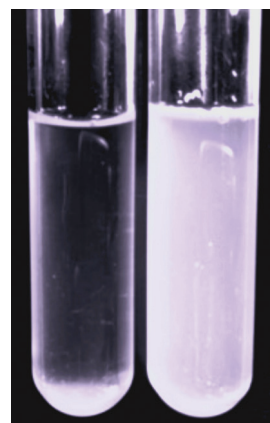


Figure 7. Auto-aggregation test at T = 24 hours (**A**) and T = 0 minutes (**B**).

The ability of many pathogenic bacteria to auto-aggregate, also called autoagglutination or flocculation, allows them to form, in vitro, multicellular clumps that eventually sink to the bottom of culture tubes (Trunk et al. 2018).

Compared to T = 24 h, most isolates showed a high potential for auto-aggregation between T = 0 min and T = 90 min, suggesting that the bacterial potential progressively accelerates throughout the initial test periods. Nevertheless, at T = 24 h, this phenomenon weakens (Fig. 8). As indicated before, periodic measurements of static cultures at 600 nm illustrate turbidity reduction at the top of the tube. The rate of auto-aggregation is indicated by the variation in optical density over time (Trunk et al. 2018).

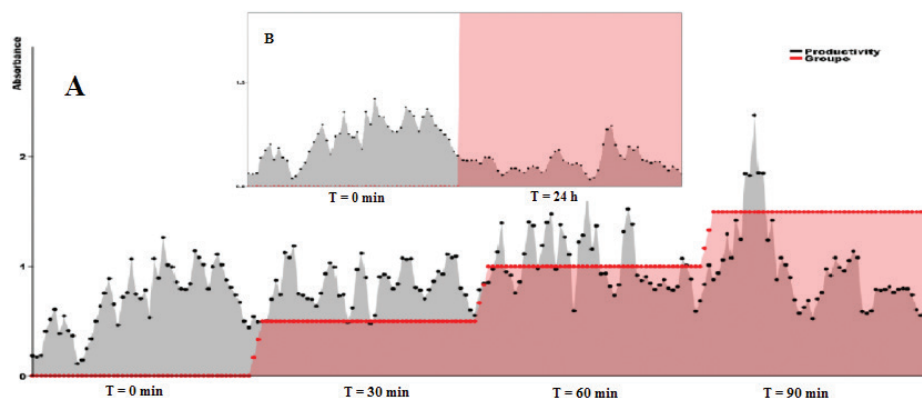


Figure 8. Auto-aggregation results (grey) as a combined histogram vs periods (red). A. At T = 0 min to T = 90 min; B. At T = 0 and T = 24 hours.

Bacterial cells aggregate and settle to the bottom of the tubes more rapidly and more compactly in a liquid culture (Nwoko and Okeke 2021). The duration of auto-aggregation can vary from a few minutes to several hours or even overnight.

To highlight the auto-aggregation phenomenon in bacteria, plotting trend lines for eight isolates showing strong potential for auto-aggregation was done since bacterial auto-aggregation seemed to be strain-dependent (Fig. 9). Based on these lines, the results showed that the auto-aggregation phenomenon followed a mathematical $Y = A X + B$ mathematical trend.

Not all strains tested showed similar regression, according to the data (Fig. 9). Only *Micrococcus* sp. and *Pentoea* sp. seemed to be correlated with

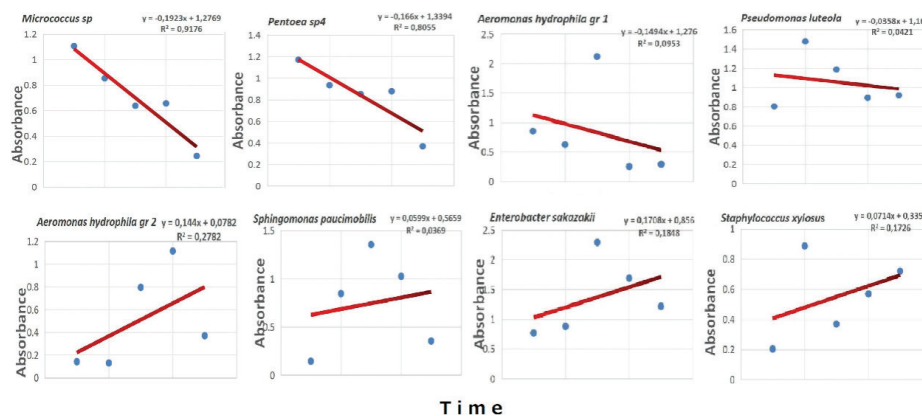


Figure 9. Regression lines of the auto-aggregation test in isolates with high auto-aggregation potential.

auto-aggregation, as indicated by the coefficient of determination (R^2) close to 0.9. However, for *Aeromonas hydrophila gr1* ($y = -0.1494x + 1.276$, $R^2 = 0.0953$) and *Pseudomonas luteola* ($y = -0.0358x + 1.163$, $R^2 = 0.0421$), the auto-aggregation behaviour seemed to be consistent with the formula $Y = -A X + B$, with a significantly reduced R^2 coefficient.

Similarly, for *Sphingomonas paucimobilis* ($y = 0.0599x + 0.5659$, $R^2 = 0.0369$), *Enterobacter sakazakii* ($y = 0.1708x + 0.856$, $R^2 = 0.1848$), *Staphylococcus xylosus* ($y = 0.0714x + 0.3356$, $R^2 = 0.1726$) and *Aeromonas hydrophila gr2* ($y = 0.144x + 0.0782$, $R^2 = 0.2782$) the coefficients of determination in all these isolates were very low. Statistical analysis of these results suggests no correlation between the two factors studied, the bacteria and auto-aggregation. In contrast to the finding of this study, auto-aggregation depends on agglutinins and strains and, thus, on the bacterial genome (Guerry et al. 2006; Bhargava et al. 2009). These observations were highlighted by Nwoko and Okeke in 2021 and subsequently confirmed by Schiffer et al. (2022) since the bacterial cell wall can affect cell aggregation and biofilm formation.

Hydrophobicity assessment

Most isolates (55%) exhibited high hydrophobicity, and 28% exhibited moderate hydrophobicity. These findings suggest that surface hydrophobicity impacts bacterial adhesion to the substrate, partly explaining why biofilm formation varies among strains. Indeed, the hydrophobic nature of the microbe surface proportionately influences biofilm formation. Bacteria with a hydrophobic surface adhere more readily to supports than those with a hydrophilic surface (Aswathy et al. 2008). Generally, the more hydrophobic the bacterial cells, the greater the adhesion is. In this context, Nowacka et al. (2021) emphasized a positive correlation between hydrophobicity and cell adhesion to a support.

Conclusion

The data from this study suggests that we should raise awareness among medical staff about the misuse and uncontrolled use of mobile phones in hospital wards. The need for vigilance was justified by the high bacterial load isolated from the surfaces of medical staff's cell phones, which reached $28 \times 10^4 \pm 120$ CFU/PS, and by the fact that these germs were resistant to several antibiotics, especially Ceftazidime. Several bacterial species were isolated from cell phone surfaces, mainly Gram-positive ones, including *Bacillus* sp. and *Micrococcus* sp. The bacterial strains tested positive for auto-aggregation, while the majority were hydrophobic. This finding is consistent with the high biofilm formation potential observed in the isolates and, consequently, the risk of infection.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

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Author contributions

S.M.L. Seddiki formulated the idea of the article and wrote the first draft. M.R. Mediouni performed the statistical analysis and discussion of the results. W. Benkhedda and M. Hafdi initiated the practical part of the study. All authors contributed equally to the conception of the article.

Author ORCIDs

Sidi Mohammed Lahbib Seddiki  <https://orcid.org/0000-0001-6055-5137>

Mohammed Reda Mediouni  <https://orcid.org/0000-0002-5514-8286>

Data availability

All of the data that support the findings of this study are available in the main text.

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