# Evaluation of an air cleaner device at a staff breakroom in a hospital environment

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**Objectives:** To test the hypothesis that the use of a portable stand-alone air cleaner in a staff breakroom within a hospital environment is effective in reducing airborne bioburden in the environment.
**Design:** Single centre, one location within the centre, two sampling conditions with a total of 18 control and 18 test days, non-randomized trial.
**Setting:** One hospital, one environment within the hospital: staff breakroom.
**Intervention:** Use of one Novaerus/Wellair Defend NV1050 air cleaner set to process air at an airflow rate of 267 CFM (453 $m^3$/h) at the named location within the hospital.
**Main outcome measure(s):** Measure of airborne bioburden as bacterial colony forming units (CFU/$m^3$) from air samples collected during control and test conditions, and identification of most prominent species found in air samples.
**Results:** Overall colony counts saw a reduction of 57.5% between control and test samples (p-value 0.053). Identification of 6 bacterial pathogens and 21 bacterial opportunistic pathogens.
**Conclusions:** The use of a portable stand-alone air cleaner in a hospital breakroom has shown substantial reduction in airborne bacterial bioburden overall.

Keywords: Air cleaner, airborne bioburden, air sampling, breakroom, field testing

## I. INTRODUCTION

The risk of airborne infection transmission has received much attention from the public and healthcare officials since the development of the COVID-19 pandemic[1–4]. However, infection transmission via the airborne route is a well known risk which has been reported in the literature well before the emergence of SARS-CoV-2[5–9].

In healthcare settings, healthcare acquired infections (HCAIs) represent an additional risk to patients and healthcare staff alike. It is known that exposure to microorganisms such as viral, bacterial or fungal pathogens can have serious effects on human health. Their effects can depend on their number and toxicity within a given environment. Indoor air quality (IAQ) is a public health concern which has been highlighted in more recent times particularly since the majority of people spend most of their time indoors.

Portable air cleaners can complement existing infection prevention measures, such as building ventilation systems, social distancing, hand and surface disinfection, and the use of masks. For example, a study by Arikan et al. (2022) has shown that the use of air purifiers can complement the ventilation system in an intensive care unit (ICU) reducing the airborne microbial load which correlated with an impact in infection rates at the ICU[10]. A separate ongoing study is investigating the cause-and-effect relationship between air purifying intervention in operating rooms (ORs) and surgical site infections (SSIs)[11].

Here we report the use of a portable air cleaner in the staff breakroom in a hospital setting. The aim of the present study is to measure airbone bioburden and to evaluate the effectiveness of a portable air cleaner in reducing the bioburden levels. In general, it is expected that lower airborne bioburden shall result in lower number of infections occurring on-site.

## II. MATERIALS AND METHODS

### II.A. Study design

The levels of airborne bioburden were measured in a staff breakroom in a hospital setting; North Shore University Hospital, 300 Community Drive, Manhasset, NY 11030. North Shore University Hospital is operated by Northwell Health which is one of the largest healthcare providers in New York with numerous locations including the Northshore University Hospital serving Long Island and Westchester. The floor area of the breakroom environment is 294 $ft^2$ (27.3 $m^2$). The ceiling height of the breakroom is 8 ft (2.4 m). The breakroom volume is 2,352 $ft^3$ (66.6 $m^3$).

The difference in bacterial bioburden levels where no air treatment device is in place (*control* or *baseline*) versus when an air cleaner is implemented (*test* or *intervention*) were compared and analysed. The airborne levels of micro-organisms were monitored using an air sampler in the staff breakroom within the facility.

Air samples were taken in two phases: *phase I* and *phase II*. Test and control samples were collected in each phase of the study. All daily samples were taken in duplicate.

The first phase of the study (phase I) comprised 6 consecutive days (Tuesday to Sunday) of control sampling from November 30 to December 5 (2021), and 6 consecutive days (Tuesday to Sunday) of test sampling from December 7 to December 12 (2021).

Following an interim review of data collected during the first phase of the study, it was decided to collect more data to improve the odds of getting a statistically significant result.

The second phase of the study (phase II) comprised 12 days of control sampling taken in two sets of 6 consecutive days from February 22 to February 27 and from March 1 to March 6 (2022), and 12 days of test sampling taken in two sets of 6 consecutive days from February 8 to February 13 and February 15 to February 20 (2022).

All samples were taken within the same time window: between 12:00 p.m. and 2:00 p.m. The air cleaner device was operated continually for the duration of the test sampling days. The air cleaner device was turned off during the control sampling days.

### II.B. Equipment used

An air cleaning device, model NV1050 – also commercialized as model Defend 1050 – (WellAir, 290 Harbor Drive, 2nd Floor, Stamford, Connecticut 06902, US), was set in the staff breakroom of the hospital. The device is a portable standalone air cleaner. Figure 1 show the location of the air cleaner within the environment.

The device was set at speed 3, 267 CFM (453 $m^3$/h) and was switched on for the duration of the test sampling periods. The device has an optional variable speed setting ranging from minimum setting of 107 CFM (181 $m^3$/h) to 533 CFM (906 $m^3$/h) at the maximum setting. The device was turned off for the duration of the control sampling periods.

A range of portable air cleaners designed to inactivate microorganisms are available from WellAir. These devices use an atmospheric plasma discharge, called NanoStrike™ Technology as their core technology. Two of the WellAir portable devices have been cleared by the Food and Drug Administration (FDA): the NV1050 and the Defend 400. The plasma technology is complemented with high-efficiency particulate arrestance (HEPA) filters in these two devices. These devices have also been challenge tested at independent laboratories against various microorganisms to show their efficacy in inactivating and removal[12].

### II.C. Sample collection and laboratory analysis

An impaction air sampler, MAS-100 Eco Microbiological Air Sampler (MBV AG, Industriestrasse 9, CH-8712 Staefa, Switzerland), was used to obtain each sample. This air sampler was calibrated by Lennox Labs, Ireland, on June 10, 2021. For sampling, the air sampler was placed on top of a breakroom table (figure 1). Every sample was taken at the same location for consistency. The air sampler was placed approximately 50 inch (1.27 m) away from the air cleaner.

Tryptone Soy Agar (TSA) was used as the media for growing and identification. This agar is a general-purpose media which can support a broad range of micro-organisms therefore ideal for this type of analysis. 9 mm pre-poured agar plates were obtained from EMSL and used with the MAS-100 Eco air sampler during sampling. The air sampler was set to collect air at a rate of 100 l/min. Each sample was collected for 1 minute, therefore sampling a 100 litre of air. Air samples were taken in duplicate, one after the other.

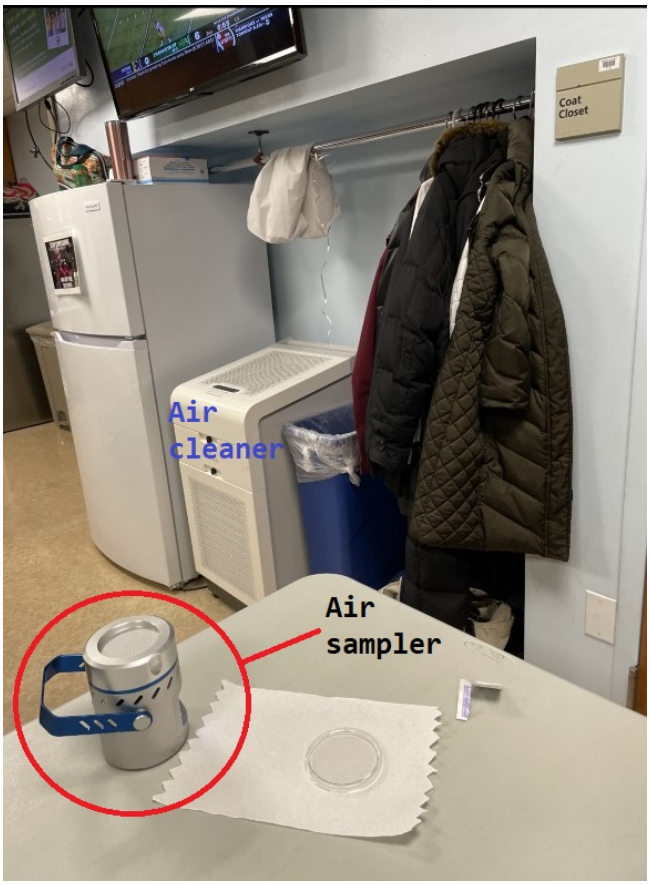


FIG. 1 Photo of the breakroom environment with the air sampler placed on a table.

A total of 72 air samples were collected: 36 during control sampling, and 36 during test sampling.

After sampling was complete, the agar plates were sealed and refrigerated for no more than 2 days and then delivered directly to external laboratory, EMSL Analytical, Inc. (200 Route 130 North, Cinnaminson, NJ 08077, USA). At the external laboratory, the plates were incubated and analysed under their code *M010 Bacterial ID (3MPT)*, following their own internal method, *MICRO-SOP-132*. This analysis had a turnaround time of two weeks. The air sample agar plates were analysed for bacterial counts which are presented as colony forming units per cubic meter (CFU/$m^3$) and identification of three most prominent species (3MPT) present in each agar plate are also reported.

### II.D. Data analysis

The data analysis comprised (1) collating the identification of most abundant species in air samples, (2) ranking the species identified by their pathogenicity (pathogens, opportunistic pathogens, non-pathogenic and unknown), and (3) enumeration of colony counts per species, per date, and overall counts.

Statistical analysis of overall colony counts to compare test and control samples comprised of determining the test statistic as per equation 1; where $\bar{x}$ is the mean value, $s$ is the sample

standard deviation (SD), and $n$ is the number of samples for each data set (control and test)[13].

$$t_{\text{stat}} = \frac{\bar{x}_{\text{test}} - \bar{x}_{\text{control}}}{\sqrt{\frac{s^2_{\text{test}}}{n_{\text{test}}} + \frac{s^2_{\text{control}}}{n_{\text{control}}}}} \quad (1)$$

The null hypothesis ($H_0$) was that the mean values of the control and test air data sample sets are the same.

$$H_0 : \bar{x}_{\text{test}} - \bar{x}_{\text{control}} = 0 \quad (2)$$

The alternative hypothesis ($H_a$) was that the mean value of the test data sample set is lower than the mean value of the control data sample set.

$$H_a : \bar{x}_{\text{test}} - \bar{x}_{\text{control}} < 0 \quad (3)$$

The probability value (p-value) of a left-tail t-student distribution (with $n-1$ degrees of freedom) for the test statistic was used to determine if the results are statistically significant. A standard cut-off probability or significance level of $\alpha = 0.05$ (5%) was used[14]. The null hypothesis is rejected if the p-value is less than the significance level; i.e., if p-value$< \alpha$ then it is highly improbable to observe a difference between the control and test data by mere chance and therefore there must be a factor affecting the air samples. In the case of the present study, the factor is the amount of additional air cleaning provided by the use of a portable stand-alone air cleaning device during the test phase.

The p-value from the initial phase (phase I) was 0.164, and with the additional data (from phases I and II combined) the p-value dropped to 0.053; a nearly-statistically significant p-value. These were calculated using a Microsoft Excel spreadsheet with built in functions for mean, sample standard deviation, t-distribution, and other mathematical expressions. The p-value indicated that the results are not statistically significant in both cases. However, the difference between test and control is clearly seen in the Box-Whisker plot in figure 2. The authors are confident that collecting additional test and control data would result in statistically significant results. A reduction of 49.4% in CFU/m$^3$ was seen in the first phase (phase I) and a reduction of 57.5% in CFU/m$^3$ was seen with the additional data; i.e., the full study (phase I and II).

## III. RESULTS

### III.A. Bacterial species identification

A total of 42 different bacterial species were identified in the agar plates analysis that were collected throughout the trial in total which are listed in table I. 30 bacterial species were identified in the control samples and a total of 24 species were identified in test samples. There were 12 common bacterial species identified among the control and test samples. No samples were taken to detect and/or identify for fungi or virus species.

The bacterial species identified were ranked by pathogenicity and summarized in table I. The first top 6 species in this table are pathogens, while the next 21 species are opportunistic pathogens. Opportunistic pathogen made up the abundance of retrieved bacteria. All other remaining species identified are deemed non-pathogenic, generalised or of unknown status.

TABLE I List of all bacterial species identified during control and test sampling.

| Pathogenicity | Bacterial Species | Control (C) / Test (T) |
|---|---|---|
| Pathogen | *Acinetobacter ursingii* | C |
| | *Staphylococcus aureus* | C |
| | *Aerococcus viridans* | C |
| | *Bacillus cereus* | T |
| | *Acinetobacter junii* | T |
| | *Staphylococcus sciuri* | T |
| Opportunistic Pathogen | *Staphylococcus hominis* | C, T |
| | *Micrococcus luteus* | C, T |
| | *Micrococcus lylae* | C, T |
| | *Staphlococcus epidermidis* | C, T |
| | *Staphlococcus haemolyticus* | C |
| | *Staphylococcus saprophyticus* | C |
| | *Roseomonas gilardii* | C |
| | *Leuconstoc lactis* | C |
| | *Roseomonas mucosa* | C |
| | *Staphylococcus cohnii* | C, T |
| | *Enterococcus faecium* | C |
| | *Corynebacterium aurimucosum* | C |
| | *Acinetobacter lwoffii* | C |
| | *Corynebacterium minutissimum* | C |
| | *Kocuria rosea* | C |
| | *Staphylococcus capitis* | T |
| | *Staphylococcus warneri* | T |
| | *Kytococcus sedentarius* | T |
| | *Acinetobacter johnsonii* | T |
| | *Klebsiella pneumoniae* | T |
| Non-Pathogen | *Dermacoccus barathri* | C |
| | *Kocuria rhizophila* | C, T |
| | *Streptococcus vestibularis* | C |
| | *Dermacoccus nishinomiyaensis* | C, T |
| | *Bacillus megaterium* | T |
| | *Bacillus sp.* | C, T |
| | *Kocuria sp.* | C |
| | *Gram positive rod* | C, T |
| | *Gram negative rod* | C, T |
| | *Gram positive cocci* | C, T |
| | *Staphylococcus sp.* | C, T |
| | *Bacillus sphaericus* | T |
| | *Rhodococcus sp.* | T |
| | *Bacillus simplex* | C |
| | *Kocuria carniphila* | C |
| | *Psychorobacter faecalis* | T |

Table II lists the colony counts of pathogens and opportunistic pathogens identified in the control and test samples. 2,670 CFU/m$^3$ were obtained during the control phase in comparison to the test phase with 1,000 CFU/m$^3$ were collected. This was an overall 63% reduction achieved in the pathogen numbers.

### III.B. Colony counts

Air samples were taken in duplicate, one after the other every day. The average of every duplicate colony count collected and analysed during both, control and test sampling, are summarized in table III.

The comparison for overall counts seen in the hospital breakroom provided a control average count of 100 CFU/m$^3$ in contrast to the test average count of 42.5 CFU/m$^3$.

TABLE II Colony counts of pathogenic and opportunistic pathogen bacterial species identified in control and test samples.

**Pathogens**

| Control | CFU/m$^3$ | Test | CFU/m$^3$ |
|---|---|---|---|
| *Acinetobacter ursingii* | 10 | | |
| *Staphylococcus aureus* | 40 | | |
| *Aerococcus viridans* | 50 | | |
| | | *Bacillus cereus* | 10 |
| | | *Acinetobacter junii* | 10 |
| | | *Staphylococcus sciuri* | 10 |
| Total | 100 | Total | 30 |

**Opportunistic Pathogens**

| Control | CFU/m$^3$ | Test | CFU/m$^3$ |
|---|---|---|---|
| *Staphylococcus hominis* | 40 | *Staphylococcus hominis* | 90 |
| *Micrococcus luteus* | 1,960 | *Micrococcus luteus* | 710 |
| *Micrococcus lylae* | 90 | *Micrococcus lylae* | 50 |
| *Staphylococcus epidermidis* | 40 | *Staphylococcus epidermidis* | 60 |
| *Staphylococcus cohnii* | 40 | *Staphylococcus cohnii* | 20 |
| *Staphylococcus haemolyticus* | 160 | | |
| *Staphylococcus saprophyticus* | 20 | | |
| *Roseomonas gilardii* | 20 | | |
| *Leuconostoc lactis* | 40 | | |
| *Roseomonas mucosa* | 30 | | |
| *Enterococcus faecium* | 10 | | |
| *Corynebacterium aurimucosum* | 40 | | |
| *Acinetobacter lwoffii* | 10 | | |
| *Corynebacterium minutissimum* | 10 | | |
| *Kocuria rosea* | 50 | | |
| | | *Staphylococcus capitis* | 10 |
| | | *Staphylococcus warneri* | 10 |
| | | *Kytococcus sedentarius* | 10 |
| | | *Acinetobacter johnsonii* | 10 |
| | | *Klebsiella pneumoniae* | 10 |
| Total | 2,570 | Total | 970 |

TABLE III Averaged air sample data collected during control and test sampling at the breakroom at the hospital site.

| | Control | | Test | |
|---|---|---|---|---|
| Phase | Date | CFU/m$^3$ | Date | CFU/m$^3$ |
| Phase I | Tue Nov 30, 2021 | 100 | Tue Dec 7, 2021 | 80 |
| | Wed Dec 1, 2021 | 55 | Wed Dec 8, 2021 | 10 |
| | Thu Dec 2, 2021 | 180 | Thu Dec 9, 2021 | 15 |
| | Fri Dec 3, 2021 | 55 | Fri Dec 10, 2021 | 45 |
| | Sat Dec 4, 2021 | 5 | Sat Dec 11, 2021 | 50 |
| | Sun Dec 5, 2021 | 0 | Sun Dec 12, 2021 | 0 |
| Phase II | Tue Feb 22, 2022 | 80 | Tue Feb 8, 2022 | 35 |
| | Wed Feb 23, 2022 | 240 | Wed Feb 9, 2022 | 5 |
| | Thu Feb 24, 2022 | 70 | Thu Feb 10, 2022 | 55 |
| | Fri Feb 25, 2022 | 130 | Fri Feb 11, 2022 | 135 |
| | Sat Feb 26, 2022 | 15 | Sat Feb 12, 2022 | 15 |
| | Sun Feb 27, 2022 | 15 | Sun Feb 13, 2022 | 35 |
| | Tue Mar 1, 2022 | 15 | Tue Feb 15, 2022 | 70 |
| | Wed Mar 2, 2022 | 590 | Wed Feb 16, 2022 | 15 |
| | Thu Mar 3, 2022 | 130 | Thu Feb 17, 2022 | 70 |
| | Fri Mar 4, 2022 | 15 | Fri Feb 18, 2022 | 30 |
| | Sat Mar 5, 2022 | 10 | Sat Feb 19, 2022 | 70 |
| | Sun Mar 6, 2022 | 95 | Sun Feb 20, 2022 | 30 |

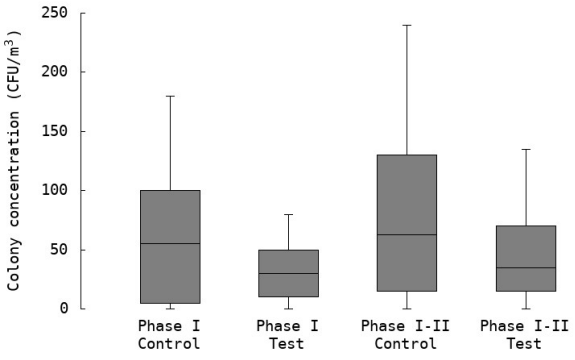


FIG. 2 Box-Whisker plot of phase I test and control data, and phase I and II test and control data.

## IV. DISCUSSION AND CONCLUSION

In healthcare settings a vast array of bacterial species can be found. This is somewhat expected since humans are the main vector of transmission, which may be through infection or carrying bacteria on clothes, hair and skin. While other microorganisms may also travel attached to particulates, dust, skin cells, within droplets and other aerosol carriers.

The species found in such settings can range broadly from harmless soil and plant bacteria to antibiotic resistant and much more pathogenic bacteria. The spectrum of organisms found from this trial found a strong contrast with this. Here non-pathogenic, opportunistic pathogens and pathogenic species were identified.

The initial average colony forming units per cubic meter (CFU/m$^3$) results from the control sampling and test sampling

with the device in place in the breakroom showed a reduction in CFU counts; 70 CFU/m$^3$ decreased to 33 CFU/m$^3$, a 58.9% reduction. All of the sample results were then analysed to compare results from control sampling (where the air cleaner device was switched off) with results from test sampling (where the air cleaner was switched on). The control sampling average was 100 CFU/m$^3$ which then saw a decrease to 42.5 CFU/m$^3$ of the test sampling average, a reduction of 53%. Although the results were not statistically significant (p-value = 0.053) the consistence of reductions seen from both phases of the test are promising as shown in figure 2. It is believed that with more sampling and a larger set of data the reductions may have seen statistical significance.

The summary of bacteria colony count concentrations reported in the literature can be found in table IV. When comparing the results obtained from this study to those identified in published literature[15–23], the counts reported here are somewhat lower. This may be due to the influx of cleaning regimes and heightened hygiene etiquette due to the current COVID-19 pandemic.

With the break room control phase in this study retrieving the average 100 CFU/m3, this is comparable to 95, 82, 69 CFU/m$^3$ counts obtained from a neonatal ward (government hospital)[21], and 79, 107, 93 seen in an operating room (government hospital)[21]. While if it is put into context other literature report main entrances and lobbies as having counts of 174, 229, 163 CFU/m$^3$ and 720 CFU/m$^3$ respectively[17,21]. However the count range in the control phase was 0–590 CFU/m$^3$.

Once the air cleaner device was deployed a decrease was seen in the bacterial counts to an average of 42.5 CFU/m$^3$. This was seen as a great change in air bioburden and can only be comparable to similar counts of 34, 25, 29 CFU/m$^3$ found in an operating room (private hospital) and a private hospital's neonatal ward with mean CFU/m$^3$ results of 33, 46, 27. Generally, neonatal wards and operating rooms would be classed as high risk areas for patients due to the activities here, and these areas would implement stricter cleaning regimes and standards. Therefore, obtaining these similar colony counts after deploying the air cleaning device is considered a very positive result. The range of counts was 0–135 CFU/m$^3$ during this test phase, notably lower than the upper scale of the control phase of 590 CFU/m$^3$.

Whilst these literature comparisons can be made, there are some other elements that need to be noted. These include different sample air volumes, different methods of collection, times; time of day/year, room or area size/volume, and the number of staff or patients along with their activities which could all impact the colony count results. It is also worth noting that there is no 'golden standard' in which air sampling can be performed and defined.

The highest colony counts that were retrieved from the hospital staff breakroom were found to be in the opportunistic pathogen classification, with the most prominent species identified being *Micrococcus luteus*. This is a common bacteria found in healthcare settings which has been associated with a variety of illnesses including meningitis, septic arthritis, endocarditis, chronic cutaneous infections in human immunodeficiency virus (HIV) positive patients, and catheter infections. A reduction in colony counts of *Micrococcus luteus* was observed from control to test measurements 1,960 CFU/m$^3$ to 710 CFU/m$^3$ (table II).

In addition to *Micrococcus* species, bacteria identified in both the control and test samples included *Staphylococcus*, *Dermacoccus* and *Acinetobacter* species. While other species identified, but not limited to, included *Bacillus* and *Corynebacterium* species. The most abundant type of bacteria were found to be opportunistic pathogens, which commonly would not cause infection or illness unless it colonizes a patient who is immunocompromised.

Non-pathogenic bacteria were also found, these were identified as normal dermal flora, soil or water bacteria or bacteria that inhabit plants. Finally, some pathogenic bacteria were found but in small numbers. This is not surprising as clothing and people can be transmitters of pathogens in hospitals and healthcare settings.

In healthcare settings bacteria and particularly pathogens are one of the biggest concerns. When the bacterial pathogen numbers were compared it was found that there was a 49.4% reduction from the initial phase I in December 2021 which then grew to a reduction of 57.5% for the full study. In addition, the pathogen numbers also saw a decrease in the initial phase I and a greater reduction in the full study data combined pathogen analysis, 37% reduction and a 63% reduction respectively. This reduction in the pathogen numbers is a positive outcome from the air cleaner device which showcases its potential in real settings.

In conclusion, reduction in colony counts between control and test sampling measurements in the hospital staff breakroom are reported here. While none of these reductions are statistically significant due to small number of samples, the overall difference and reduction show encouraging results. The data collected and reported in this study suggests that the use of a portable stand-alone air cleaning device may reduce the airborne bacterial bioburden at a staff breakroom in a hospital setting. Further testing in this hospital or in similar settings is recommended to evaluate the performance of the air cleaning in more depth.

## ACKNOWLEDGMENTS

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TABLE IV Airborne sample colony counts (CFU/m$^3$) as reported in the literature.

| Area | Range (CFU/m$^3$) | Mean (CFU/m$^3$) | Reference |
|---|---|---|---|
| Clinical outpatient rooms | | 1,000 | Pastuszka et al. (2005)[18] |
| Hospital rooms | 4–1,293 | 124 | Ortiz et al. (2008)[20] |
| Hospitals in Poland | 100–1,000 | | Pastuszka et al. (2005)[18] |
| Patient rooms (gov. hospital) | | 198, 254, 185 | Qudiesat et al. (2009)[21] |
| Patient rooms (private hospital) | | 145, 163, 137 | Qudiesat et al. (2009)[21] |
| Ward | 42–325 | | Obbard & Fang (2003)[17] |
| Maternity wards | 14–224 | 67 | Ortiz et al. (2008)[20] |
| Neonatal ward (gov. hospital) | | 95, 82, 69 | Qudiesat et al. (2009)[21] |
| Neonatal ward (private hospital) | | 33, 46, 27 | Qudiesat et al. (2009)[21] |
| Pneumonological dept. | 257–436 | | Augustowska & Dutkiewicz (2006)[19] |
| ICU (gov. hospital) | | 109, 107, 121 | Qudiesat et al. (2009)[21] |
| ICU (private hospital) | | 149, 197, 147 | Qudiesat et al. (2009)[21] |
| Operating room | 25–847 | 370 | Greene et al. (1962)[15] |
| Operating room (gov. hospital) | | 79, 107, 93 | Qudiesat et al. (2009)[21] |
| Operating room (private hospital) | | 34, 25, 29 | Qudiesat et al. (2009)[21] |
| Operating rooms | 35–6,356 | | Favero et al. (1968)[16] |
| Operating theatres | 1–157 | | Ortiz et al. (2008)[20] |
| Overall hospital areas | 353–2,472 | | Greene et al. (1962)[15] |
| Lobbies | | 720 | Park et al. (2013)[22] |
| Lobby | 445–890 | | Obbard & Fang (2003)[17] |
| Main enterance (gov. hospital) | | 174, 229, 163 | Qudiesat et al. (2009)[21] |
| Main enterance (private hospital) | | 120, 115, 87 | Qudiesat et al. (2009)[21] |
| Pharmacy | 201– 827 | | Obbard & Fang (2003)[17] |
| Personal (cleaners) | 103– 1,710 | 351 | Lu et al. (2020)[23] |
| Waste storage | | 6,709 | Greene et al. (1962)[15] |
| Industrial clean rooms | 35–353 | | Favero et al. (1968)[16] |

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