Comparison Between Indoor Air Quality Of Private And Governmental Health Care Institution

Wafaa Menawi (w.menawi@najah.edu)
An-Najah National University
alaa darwazeh
An-Najah National University
tasbeeh ateeq
An-Najah National University
rahaf sobuh
An-Najah National University
taimaa abu haneesh
An-Najah National University

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Abstract

Background

Indoor air quality is "of interest" to scientists and specialists in the fields of science because of its importance in maintaining the health of individuals, as the air can transmit various microbes, including pathogenic ones.

Poor indoor air quality may significantly affect the increase in the incidence of various types of diseases, especially for those with immunodeficiency diseases. So, the hospital environment requires special attention to ensure healthy indoor air quality (IAQ) to protect the patient, patient's family, and health care workers from an infection acquired by hospitals and occupational diseases.

Objectives

This study aimed to identify the different types of airborne bacteria and fungi among private and governmental health care institutions, An-Najah National University Hospital (NNUH) and Rafidia Governmental Surgical Hospital.

Another aim was to evaluate the relationship between the spread of different types of them and the characteristics of the surrounding atmosphere such as temperature and humidity.

As well as, it aimed to compare the results before and during the COVID-19 Pandemic; to find the effect of adhering to the public health and safety guidelines imposed by the Ministry of Health (MOH).

Materials and Methods

Samples were collected by passive method from two different hospitals at five departments where most activities and tasks are performed inside, Besides two different sites outside the hospital, in an average of three hours.

The positive colonies were identified by using several biochemical tests. Then, the Total Microbial Load (CFU/plate) was calculated for each plate.

Furthermore, the temperature and humidity of each room from which samples were taken were also measured to find the relationship between them and the percentage of microbial airborne.

Results

The predominant Gram-positive bacteria in Rafidia Governmental Surgical Hospital was S. aureus that presents in daycare and emergency departments, and Aer. hydrophila gr.1 among Gram-negative bacteria found in the surgical department.

While in NNUH, the predominant Gram-positive bacteria were S. epidermidis and S. saprophyticus that present in departments of surgery and laboratories, respectively. and Pseudomonas luteola among Gram-negative bacteria found in daycare department.

Also, the level of airborne microbial pollutants in Rafidia Governmental Surgical Hospital appeared in greater proportions than in NNUH, as it reached in Rafidia Governmental Surgical Hospital (12430.1188 CFU/m^3), while in NNUH (11779.3501 CFU/m^3)

Besides, it was also found that the levels of microbial airborne in confined and crowded areas are much higher than in sparsely populated areas. Besides, the percentage was also high in rooms with high temperature and humidity.

Conclusions

The levels of airborne microbes were affected by the surrounding area according to the degree of crowding, temperature, and humidity. Because of these factors, we concluded that Rafidia Governmental Surgical Hospital is more polluted with microbial airborne, another reason could be due to the smallness of its facilities compared to NNUH. In this study, we will note the evidence and results that confirm our conclusion.

Besides, compared with previous studies, we concluded that infection levels during the Corona pandemic period are lower than the pre-pandemic period, which means that there's a commitment by the hospital's staff and patients to the public health and safety guidelines imposed by MOH including the necessary sterilizations, wearing a mask and maintaining social distancing.

**The comparison occurred in one common section between the two studies, which is the Department of Surgery

Introduction

The main role of the hospital is to provide full medical treatment; the most important of which is nursing care for patients. Many departments are represented in health care such as operating theaters, intensive care units (ICUs), outpatient departments (OPDs), etc. (Leung1ABCDEF & Chan2ADEF, 2006). Besides, it is one of the workplace environments that can be easily contaminated with a variety of occupational risks, such as infectious materials or contaminated equipment, as well as blood and other body fluid from patients. Healthcare staff is oftentimes susceptible to health hazards in the hospital environment, including bioaerosol (Luksamijarulkul et al., 2019).

With the continuous development in the quality of life, researchers during the twenty-first century have put the breathing environment in the limelight. Numerous studies contend that indoor air is more dangerous than outdoor air (Saini, Dutta, & Marques, 2020), because most individuals spend around 90% of their time indoors, so the quality of the indoor environment has a significant impact on humans' well-being. therefore, the scientific community has become increasingly worried about the bearings of indoor air quality on health during the last two decades (Jones, 1999).

Indoor air quality is viewed as one of the most critical aspects that must be taken into consideration in hospitals. Consequently, it should be healthful to protect the patient, patient's family, and healthcare workers from being exposed to infections (El-Sharkawy & Noweir, 2014). More precisely, there is a pressing need to

protect the patients who are at a higher risk to be affected by various airborne microbe easily than other patients, and this includes immunocompromised patients (Leung1ABCDEF & Chan2ADEF, 2006).

Microbial air contamination can be bacterial or fungal which is considered as an indicator of healthy indoor quality (Božić & Ilić, 2019). The indoor air quality may be affected by the indoor bioaerosol contaminant that originates from the hospital equipment, machines, seats, and personal activities for healthcare workers and patients. Furthermore, smoking is considered one of the main causes of indoor air contamination, so all Health Care Facilities HCF must ban smoking and impose severe consequences for those who violate this rule. In addition, the outdoor quality in human breathing zones can be easily polluted by the outdoor contaminant that may come from different sources such as mobile sources, such as (cars, buses, etc.). This source may be due to the traffic that surrounds the hospital (El-Sharkawy & Noweir, 2014). Accordingly, Microbial contamination could be reduced by regulating human activities, ventilation rates, and filtration efficiency. However, a better understanding of the sources and reservoirs of airborne microorganisms is required for mitigation and prevention (Osman et al., 2018).

In 2015, a Taiwan study conducted by Jung about indoor air pollutants in hospitals and their association with different types of bacteria and fungi in 96 sites from 37 hospitals, It was found that the fungal concentrations were higher at the hospitals with non-central air conditioning systems ($p < 0.05$). (Jung, Wu, Tseng, & Su, 2015).

Verde conducted a study in the Portuguese hospital in the same year, the numbers of airborne bacteria and fungi were assessed by conducting a bioaerosol quality survey at different locations in the hospital. Gram-positive cocci bacteria were dominant among the bacterial genera (88%): Staphylococcus (51%) and Micrococcus (37%). Whereas the prevalent genera of fungus were Penicillium (41%) and Aspergillus (24%) (Verde et al., 2015).

In 2019, a study in South Korea mentioned that air transport is one of the main ways for the spread of several infectious diseases. Inadequate ventilation can facilitate the spread of viruses transmitted through infectious aerosols caused by patients coughing or sneezing - such as the coronavirus that causes Middle East Respiratory Syndrome (MERS) (Cho, Woo, & Kim, 2019).

Another study in 2018, aimed to measure the concentrations of microorganisms (bacteria, fungi, and viruses) during two periods (winter and summer) in 7 rooms in two French hospitals. The results have shown that indoor air contains a complex combination of physical, chemical, and microbiological compounds. (Baurès et al., 2018).

A study in 2016 was done in Rafidia Governmental Surgical Hospital to identify bacteria in the air of different sections of it. Results of this research showed that the total count of Gram-positive bacteria; coagulase-negative staphylococci (CoNS) and Micrococcus spp. were the most predominant among isolated bacteria from air samples in the neonatal room (NR), intensive care unit (ICU), and surgical operation rooms (SOR). (air sampling has ranged from 61.8%-100% and the average was 5158 CFU/m2 /h to 17753 CFU/m2 /h).(Adwan, Abedraboo, Adwan, & Al-Sheboul, 2016).

Our study was conducted during the pandemic of covid19 to determine the level of airborne bacterial and fungal pollutants that may affect the air quality in hospitals, and it aimed to compare the indoor and outdoor air quality of private and governmental health care institutions. As well as to determine how the levels of microbial airborne contamination were affected by the existence of the Corona pandemic.

Method

Study Area and Site of Samples Analysis

An-Najah National University Hospital (NNUH) is a private, non-profit hospital that is Palestine's teaching hospital, providing both education and health services. It is also the first academic medical center hospital in Palestine to receive Joint Commission International accreditation (JCI). NNUH was established in 2013 in partnership with the Faculty of Medicine and Health Sciences (FMHS) at An-Najah National University. It is located in the northwestern mountainous area of Nablus, on the exit that leads to the town of Asira Ash-Shamaliya. And it has five main departments, with 135 beds and plans to expand to nearly 500. It also hosts the clinical research office that is attached to the medical education office at FMHS.

Rafidia Governmental Surgical Hospital is one of the fourteen Palestinian governmental hospitals operating in the West Bank, Followed by the Palestinian MOH, with a capacity of 200 beds and 628 employees. It was built in 1976, and it is one of the largest health institutions in the northern West Bank.

Our study is an experimental cross-sectional study, whereas the hospital's air samples were collected from five various departments inside two different hospitals, which are: medical laboratories, emergency department, daycare unit, surgery department, and staff department. As well as two different outside of them, in a period extending between November and December of 2021.

The collected samples were incubated, cultured, and identified in the Department of Biology and Biotechnology, Science College, An-Najah National University, City of Nablus-Palestine.

Air sampling

The samples were collected by the passive method in which putting open petri dishes containing different culture media such as nutrient agar (NA) that allow the growth of various types of bacteria, and sabouraud dextrose agar (SDA) that allow the growth of fungi. The last one was modified with chloramphenicol -an antibiotic used to inhibit bacterial growth-.

A single petri dish from each media was placed in different places of the selected departments and two outdoor sites at a high 1 m above the breathing zone.

A duplicated sample was done during different periods and the counts obtained were averaged. The time extends up to three hours for each time, the first sampling was from 11 to 2 pm during November and the second was from 9 to 12 Am during December.

We faced some challenges while placing samples in the selected departments, but with helping of officials and staff and in full compliance with public health and safety guidelines, we were able to successfully collect

samples.

Microbiological procedure

After the exposure time, samples were taken to the laboratory (Faculty of Medicine and Health Sciences, An-Najah National University) and incubated at 37°C for 24 h for bacteria and 25°C for 3–5 d for fungi. Then positive colonies were counted in both media (NA/SDA)

After counting the colonies, CFU/m3 were determined according to an equation called Omeliansky's formula, which is:

N = 5a x 10^4 /(bt)

Where:

N is the microbial CFU/m3 of indoor air,

a is the number of colonies per Petri dish for the time t,

b is the Petri dish surface area (cm2),

t is the exposure time (min).

Then, identification of isolates was done according to standard methods.

Codes nomenclature for sampling

Sample codes were named according to the first letters of the hospital, department, and room, respectively

Example

Room No. 502 in Day Care Department (DC), An-Najah National University Hospital (N)

→ NDC502

See Table.1 shows the full name of the study codes

Environmental Condition Of Investigated Departments

Samples were collected at different times on different days under different environmental conditions.

See Table.2 and Table.3 show the temperature and humidity of the targeted rooms in both hospitals, as well as the number of rooms and beds in each department.

Table 1
Full name of the study codes

Codes	Full Name
RS1	**S**urgical department room No.**1**
RS3	**S**urgical department room No.**3**
RSP	**S**taff department in **P**ersonnel room
RSS	**S**taff department in **S**ecretarial room
RLBB	**L**aboratory in **B**lood **B**ank
RLR	**L**aboratory in **R**outine section
RDCP	**D**ay**c**are unit in **P**atient room
RDCO	**D**ay**c**are unit in **O**perations room
RER	**E**mergency in **R**eception
REP	**E**mergency in **P**atient room
ROED	**O**utdoor at the **E**mergency **D**oor
ROMD	**O**utdoor at the **M**ain **D**oor
NS2427	**S**urgical department room No.**2427**
NS2411	**S**urgical department room No.**2411**
NSR	**S**taff department in **R**eception
NSG724	**S**taff department room No.**G724**
NL1108	**L**aboratory room No.**1108**
NL1117	**L**aboratory room No.**1117**
NDC502	**D**ay**c**are unit room No.**502**
NDC510	**D**ay**c**are unit room No.**510**
NER	**E**mergency in **R**eception
NEP	**E**mergency in **P**atient room
NOED	**O**utdoor at **E**mergency **D**oor
NOCTW	**O**utdoor at **C**linical **T**raining **W**indow

Table 2

Rafidia Governmental Surgical Hospital

Departments	Room Code	Temperature (°C)	Moisture (%)	# rooms	# beds
Surgical Dept.	RS1	1st → 18	1st → 70	7	14
		2nd → 20	2nd → 50		
	RS3	1st → 21	1st → 73		
		2nd → 25	2nd → 55		
Staff Dept.	RSP	1st → 22	1st → 73	7	-----
		2nd → 26	2nd → 55		
	RSS	1st → 22	1st → 73		
		2nd → 26	2nd → 55		
Laboratory Dept.	RLBB	1st → 17	1st → 69	-----	-----
		2nd → 20	2nd → 51		
	RLR	1st → 17	1st → 69		
		2nd → 20	2nd → 71		
Day Care Dept.	RDCP	1st → 18	1st → 72	2	6
		2nd → 21	2nd → 50		
	RDCO	1st → 18	1st → 72		
		2nd → 21	2nd → 50		
Emergency Dept.	RER	1st → 21	1st → 75	12	26
		2nd → 27	2nd → 57		
	REP	1st → 21	1st → 75		
		2nd → 27	2nd → 57		
Outdoor	ROED	1st → 20	1st → 75	-----	-----
		2nd → 26	2nd → 55		
	ROMD	1st → 20	1st → 75		
		2nd → 26	2nd → 55		

Table 3
An-Najah National University Hospital

Departments	Room Code	Temperature (°C)	Moisture (%)	# rooms	# beds
Surgical Dept.	NS2427	1st → 25.8	1st → 32	20	23
		2nd → 26.9	2nd → 42		
	NS2411	1st → 24.9	1st → 34		
		2nd → 28.5	2nd → 46		
Staff Dept.	NSR	1st → 22	1st → 48	19	-----
		2nd → 25	2nd → 43		
	NSG724	1st → 24.8	1st → 48		
		2nd → 25	2nd → 43		
Laboratory Dept.	NL1108	1st →24.2	1st → 46	19	-----
		2nd → 28.2	2nd → 42		
	NL1117	1st → 25.8	1st → 29		
		2nd → 27.2	2nd → 31		
Day Care Dept.	NDC502	1st →24.5	1st → 50	12	14
		2nd → 26.6	2nd → 47		
	NDC510	1st → 21.5	1st → 50		
		2nd → 21.6	2nd → 47		
Emergency Dept.	NER	1st → 20.7	1st → 45	2	9
		2nd → 23	2nd → 25		
	NEP	1st → 20.7	1st → 45		
		2nd → 23	2nd → 25		
Outdoor	NOED	1st → 23	1st → 73	-----	-----
		2nd → 28	2nd → 56		
	NOCTW	1st → 23	1st → 73		
		2nd → 28	2nd → 56		

Microbiological analysis and identification

For identification of bacterial colony growth on NA, the isolated colonies were cultured on blood agar (BA) and macConkey agar (MA); to differentiate between the gram-negative and positive bacteria, then incubated at 37 C° for 24h.

After the end of the incubation period, a suspension of bacteria with sterile normal saline was done on a slide for the microscopic examination to determine the morphology for the isolated bacteria if it is cocci or bacilli.

For gram-positive cocci bacteria, further tests were carried out to identify the type of the isolated bacteria by performing different biochemical tests. A catalase test was done to differentiate between the staphylococcus and streptococcus species. then coagulase test was done for catalase-positive bacteria to distinguish between the staphylococcus species. Novobiocin sensitivity test was done for coagulase-negative bacteria to differentiate between S.saprophyticus and S.epidermidis.

Gram-positive bacilli bacteria were subcultured on BA and incubated at 37 C° for 24h. A smear of the obtained colony was prepared on a slide, air-dried, and heat-fixed. A spore stain with malachite green stain was carried out on the prepared slide, placed a filter paper on the fixed smear and while exposed to steam flood the smear and paper with stain for 10 min, decolorized the slide with water and stained it with safranin as a counterstain for 30 seconds. Then examined the slide under the microscope.

For gram-negative bacteria that grew on MA, the isolated bacteria were subcultured on BA and MA again, then incubated.

at 37 C° for 24h, after the end of the incubation period, a suspension of bacteria was prepared with sterile normal saline and injected into the API tubes for incubation at 37 C° for 24h. Then the results were read according to the book designated for the API test, identifying the type of bacteria.

Fungi that grew on SDA media were identified according to their appearance and texture. Wet mount was prepared from the colony and examined under the light microscope to distinguish between molds and yeast.

Related Terms:

 BA: is an enriched media and differential media that allow the growth of both positive and negative gram bacteria

 MA: is media that contain bile salts and crystal violet that inhibit the growth of gram-positive while allowing the growth of gram-negative.

 Catalase test: It's done by transferring a small amount of colony using a loop or sterile wooden stick to a clean, dry glass slide. Then put a drop of 3% H2O2 on the slide and observe the formation of oxygen bubbles.

- A positive test is when Copious bubbles are produced.
- A negative test is when No or very few bubbles are produced.

 Coagulase test: is done by adding about 10 µl of deionized water or physiological saline to a slide. then, colonies from samples are collected with a loop and emulsified into the water to obtain a smooth milk-colored suspension, and the clumping is observed immediately, not to exceed 10 seconds.

- A positive test is the demonstration of the agglutination
- A negative test is demonstrated by the lack of agglutination

 Novobiocin sensitivity test: for this test a suspension of bacteria with sterile normal saline was prepared and cultured on Molten agar and the novobiocin disc was placed at the center of the plate then incubated for 24h. At the end of incubation, looked for a clear zone around the novobiocin disc.

- When the diameter is greater than 16mm, it's S.epidermidis
- When the diameter is less than 16mm, it's S.saprophyticus

 API test -Analytical Profile Index-: is a classification of bacteria based on biochemical tests, allowing fast identification.

In this test, TDA reagent was added to a strep contained TDA test, JAMES reagent was added to IND test strep, VP1 and VP2 reagents were added to VP test strep, Ni1 and Ni2 reagents were added for GLU test strep.

Tables 4,5,6,7 show the results of the biochemical tests.

Table 4
biochemical test for gram-positive bacteria in Rafidia Governmental Surgical Hospital – 1st time

	Gram	Shape	Catalase Test	Coagulase Test	Novobiocin Test
RS1 white colonies	+	Cocci	+	-	28mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	34mm (S. epidermidis)
RS3	-	According to API Test, it's Aer. hydrophila gr. 1			
RLR	+	Cocci	+	-	28mm (S. epidermidis)
RLBB	+	Cocci	+	+	S. aureus
RDCO	+	Cocci	+	+	S. aureus
RDCP	+	Cocci	+	-	23mm (S. epidermidis)
RSP white colonies	-	According to API Test, it's Past. Pne/Mann. Haem			
yellow colonies	-	According to API Test, it's Past. Pne/Mann. Haem			
RSS	-	According to API Test, it's Aci. Baumannii			
RER	+	Cocci	+	-	25mm (S. epidermidis)
REP	+	Cocci	+	+	S. aureus
ROMD	-	According to API Test, it's ser. Rubidaea			
ROED	+	Cocci	+	+	S. aureus

Table 5
biochemical test for gram-positive bacteria in Rafidia Governmental Surgical Hospital – 2nd time

	Gram	Shape	Catalase Test	Coagulase Test	Novobiocine Test
RS1	+	Cocci	+	-	28mm (S. epidermidis)
RS3 white colonies	-	According to API Test, it's Aci. Baumannii			
yellow colonies	-	According to API Test, it's Aci. Baumannii			
RLR white colonies	+	Cocci	+	-	27mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	resistance (S. saprophyticus)
RLBB	+	Cocci	+	-	resistance (S. saprophyticus)
RDCO	+	Cocci	+	-	25mm (S. epidermidis)
RDCP white colonies	+	Cocci	+	-	27mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	24mm (S. epidermidis)
RSP	+	Cocci	+	-	resistance (S. saprophyticus)
RSS white colonies	+	Cocci	+	+	S. aureus
yellow colonies	+	Bacilli			
RER white colonies	+	Cocci	+	-	26mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	30mm (S. epidermidis)
REP white colonies	+	Cocci	+	-	34mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	15mm (S. saprophyticus)
ROMD	+	Cocci	+	-	25mm (S. epidermidis)
ROED white colonies	+	Cocci	+	-	25mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	28mm (S. epidermidis)

Table 6
biochemical test for gram-positive bacteria in NNUH – 1st time

	Gram	Shape	Catalase Test	Coagulase Test	Novobiocine Test
NS2427	+	Cocci	+	-	23mm (S. epidermidis)
NS2411 white colonies	+	Cocci	+	-	27mm (S. epidermidis)
yellow colonies	-	According to API Test, it's Aci. baumannii			
NL1108	+	Cocci	+	-	15mm (S. Saprophyticus)
NL1117	+	Cocci	+	-	13mm (S. Saprophyticus)
NDC502	-	According to API Test, it's Ps. Luteola			
NDC510	-	According to API Test, it's photo. Damselae			
NSR	+	Bacilli			
NSG724 white colonies	+	Cocci	+	-	20mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	30mm (S. epidermidis)
NER	+	Cocci	+	-	20mm (S. epidermidis)
NEP	-	According to API Test, it's Aci. baumannii			
NOCTW	-	According to API Test, it's Aer. hydrophila gr.2			
NOED	-	According to API Test, it's Aci. baumannii			

Table 7
biochemical test for gram-positive bacteria in NNUH – 2nd time

	Gram	Shape	Catalase Test	Coagulase Test	Novobiocin Test
NS2427 white colonies	+	Cocci	+	-	21mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	30mm (S. epidermidis)
NS2411 white colonies	+	Cocci	+	-	22mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	32mm (S. epidermidis)
NL1108	+	Cocci	+	-	22mm (S. epidermidis)
NL1117 white colonies	+	Cocci	+	-	27mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	30mm (S. epidermidis)
NDC502	+	Cocci	+	-	24mm (S. epidermidis)
NDC510	+	Cocci	+	-	23mm (S. epidermidis)
NSR white colonies	+	Cocci	+	-	22mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	38mm (S. epidermidis)
NSG724 white colonies	+	Cocci	+	-	23mm (S. epidermidis)
yellow colonies	+	Cocci	+	-	35mm (S. epidermidis)
NER white colonies	+	Cocci	+	-	26mm (S. epidermidis)
yellow colonies	+	Cocci	+	+	S. aureus
NEP white colonies	+	Cocci	+	-	29mm (S. epidermidis)
yellow colonies	-	According to API Test, it's Aci. baumannii			
NOCTW	-	According to API Test, it's Aci. baumannii			
NOED white colonies	+	Cocci	+	-	resistance (S. saprophyticus)
yellow colonies	-	According to API Test, it's v. fluvialis			

Sample disposal

In order to preserve public health first and environment secondly, samples containing bacteria and fungi were properly and safely destroyed in the Microbiology Laboratory located in the basement 1 floor of the Faculty of Medicine and Health Sciences at An-Najah National University.

Results

Airborne microbes were identified from five departments in the indoor air as well as two different sites in the outdoor air of the two hospitals by taking 96 samples. The results were as follows

Surgical Departments

Gram-negative bacteria were found in prevalent numbers than gram-positive bacteria in Rafidia Governmental Surgical Hospital. Air in the surgical departments was found to contain Aeromonas hydrophila grade 1 (2183.787561 CFU/m^3) as the predominant gram-negative bacteria, with Relatively few numbers of Acinetobacter baumannii (414.9196366 CFU/m^3). Among gram-positive bacteria, S. epidermidis (436.7575122 CFU/m^3) was found as the predominant one.

The predominant isolated bacteria from the surgical department of NNUH was gram-positive bacteria, the air was rich in S. epidermids (2856.394 CFU/m^3), while a small amount of Acinetobacter baumannii (537.21174 CFU/m^3) was founded as the gram-negative bacteria.

Yeast was founded as the predominant fungi in both hospitals, (48.04333 CFU/m^3) in Rafidia Hospital, and (26.20545 CFU/m^3) in NNUH.

Medical Laboratory

Medical laboratories of both Rafidia and NNUH were found to contain a greater number of gram-positive bacteria only without gram-negative bacteria. Various species of staphylococcus were found in Rafidia Governmental Surgical Hospital, like S. aureus (240.2166317 CFU/m^3), S. epidermidis (305.7302586 CFU/m^3), and S.saprophyticus (69.8812 CFU/m^3) as gram-positive bacteria. Among these species, the S.epidermidis was found to be the predominant one, whereas the S. saprophyticus (2384.696017 CFU/m^3) was found to be predominant in NNUH, and S. epidermidis (144.1299791 CFU/m^3) was also found in a small amount.

Besides bacteria, yeast (21.83788 CFU/m^3) was found in Rafidia Governmental Surgical Hospital, while NNUH was found to be free from fungi.

Daycare Unites

Only S. aureus (2183.787561 CFU/m^3) and S. epidermidis (432.3899 CFU/m^3) were isolated from Rafidia Governmental Surgical Hospital as gram-positive bacteria with the S. aureus as the predominant one.

While in NNUH, Gram-negative bacteria were found in more prevalent numbers than gram-positive bacteria. Air was found to contain pseudomonas luteola (2183.787561 CFU/m^3) as the predominant gram-negative bacteria with Relatively few numbers of photobacterium damselae (257.6869322 CFU/m^3). Among gram-positive bacteria, S.epidermidis (489.1684 CFU/m^3) was found as the predominant one.

Apart from bacteria, small amount of yeast was found in both hospitals with the approximately same percentage (8.73515 CFU/m^3).

Emergency Department

Different species of staphylococcus were found in the emergency department of Rafidia Governmental Surgical Hospital as Gram-positive bacteria, like S. aureus (2183.787561 CFU/m3), S. epidermidis (939.0287 CFU/m3), and S.saprophyticus (21.83787561 CFU/m3). Among these species, the S.aureus was found to be the predominant one. And it was found to be free from gram-negative bacteria.

While in NNUH, Gram-positive bacteria were found in more prevalent numbers than gram-positive bacteria. Air was found to contain S.epidermidis (218.3788 CFU/m3) as the predominant gram-negative bacteria with Relatively few amounts of S.aureus (4.367575122 CFU/m3). Among gram-negative bacteria, Aci. baumannii (109.1893781 CFU/m3) was found as the predominant one.

Yeast was found as the predominant fungi in both hospitals, in a greater percentage in Rafidia Hospital, where it's (34.9406 CFU/m3). While it's (21.83788 CFU/m3) in NNUH

Staff Department

The gram-negative bacteria were found in a greater number than gram-positive bacteria in the staff department of Rafidia Governmental Surgical Hospital. The isolated gram-negative were Aci. Baumannii (519.7414396 CFU/m^3) and Past. Pne/Mann. Haem (397.4493361 CFU/m^3), the predominant one was Aci. Baumannii. While the isolated gram-positive bacteria were S. saprophyticus (593.9902166 CFU/m^3) and S. aureus (244.5842068 CFU/m^3), the predominant one was S. saprophyticus.

While in NNUH, only S.epidermidis (633.2984 CFU/m^3) was present as Gram-positive bacteria.

Aerobic bacilli bacteria were also present in both hospitals, with a greater percentage in NNUH. where it's (292.6275332 CFU/m^3). While it's (13.10272537 CFU/m^3) in Rafidia Governmental Surgical Hospital.

Besides bacteria, yeast was found as the predominant fungi in both hospitals, in a greater percentage in Rafidia Hospital, where it's (21.83788 CFU/m^3). While it's (8.735150245 CFU/m^3) in NNUH

Outdoor

The outdoor air in Rafidia Governmental Surgical Hospital was found to be rich in gram-positive bacteria than gram-negative bacteria. Among the gram-positive bacteria that were isolated, the S.epidermidis (537.21174 CFU/m^3) and S. aureus (528.4765898 CFU/m^3) was predominant in almost the same proportion. Among gram-negative bacteria, Serratia rubidaea (428.022362CFU/m^3) was only found.

The outdoor of NNUH was found to contain a greater number of gram-negative bacteria than gram-positive bacteria. Different types of gram-negative bacteria were found, like Aeromonas hydrophila grade 2 (397.4493361 CFU/m^3), Acinetobacter baumannii (803.633823 CFU/m^3), and vibrio fluvialis (21.83787561 CFU/m^3), among these types the predominant was Aci. baumannii. while the predominant gram-positive bacteria found was S. saprophyticus (314.4654088 CFU/m^3).

Besides bacteria, yeast was also present in both hospitals, in a greater percentage in NNUH, where it's (65.5136268 CFU/m^3). While it's (56.7784766 CFU/m^3) in Rafidia Governmental Surgical Hospital.

The results of Rafidia Governmental Surgical Hospital and NNUH are indicated in Tables 8,9 respectively.

Table 8
Average of bacterial and fungal CFU/m3 air number during a different time of day at a different time of exposure in Rafidia Governmental Surgical Hospital

Sampling Location	Room Number	Media used for sampling	Findings	Colony-forming units/plate	Total Microbial Load (CFU/m3)	Level of contamination*
surgical department	1	NA	S. epidermidis	100	436.7575122	Intermediate
		SDA	Yeast	4	17.47030049	Low
	3	NA	Aer. hydrophila gr.1	> 500	2183.787561	High
			Aci. baumannii	95	414.9196366	Intermediate
		SDA	Yeast	7	30.57302586	Low
medical laboratories	Routine section	NA	S. epidermidis	70	305.7302586	Intermediate
			S. saprophyticus	1	4.367575122	Low
		SDA	Yeast	3	13.10272537	Low
	Blood Bank	NA	S. aureus	55	240.2166317	Low
			S. saprophyticus	15	65.51362683	Low
		SDA	Yeast	2	8.735150245	Low
Daycare unit	operations room	NA	S. aureus	> 500	2183.787561	High
			S. epidermidis	15	65.51362683	Low
		SDA	Yeast	1	4.367575122	Low
	Patient room	NA	S. epidermidis	84	366.8763103	Intermediate
		SDA	Yeast	1	4.367575122	Low
Staff department	Personnel room	NA	S. saprophyticus	136	593.9902166	High
			Past. Pne/Mann. haem	91	397.4493361	Intermediate
		SDA	Yeast	3	13.10272537	Low
	Executive Secretarial Room	NA	Aci. baumannii	119	519.7414396	High

* The level of contamination was classified into 3 levels: <300 cfu/m3, 300–500 cfu/m3, and > 500 cfu/m3, according to a similar study in Thailand. (Luksamijarulkul et al., 2019)

Sampling Location	Room Number	Media used for sampling	Findings	Colony-forming units/plate	Total Microbial Load (CFU/m3)	Level of contamination*
			S. aureus	56	244.5842068	Low
			Bacilli	3	13.10272537	Low
		SDA	Yeast	2	8.735150245	Low
Emergency department	Reception	NA	S. epidermidis	179	781.7959469	High
		SDA	yeast	2	8.735150245	Low
	Patient room	NA	S. aureus	> 500	2183.787561	High
			S. epidermidis	36	157.2327044	Low
			S. saprophyticus	5	21.83787561	Low
		SDA	yeast	6	26.20545073	Low
Outdoor	At the main door	NA	ser. rubidaea	98	428.022362	Intermediate
			S. epidermidis	40	174.7030049	Low
		SDA	yeast	2	8.735150245	Low
	At the emergency door	NA	S. aureus	121	528.4765898	High
			S. epidermidis	83	362.5087352	Intermediate
		SDA	yeast	11	48.04332635	Low

* The level of contamination was classified into 3 levels: <300 cfu/m3, 300–500 cfu/m3, and > 500 cfu/m3, according to a similar study in Thailand. (Luksamijarulkul et al., 2019)

Table 9
Average of bacterial and fungal CFU/m3 air number during a different time of day at a different time of exposure in NNUH.

Sampling Location	Room Number	Media used for sampling	Findings	Colony-forming units/plate	Total Microbial Load (CFU/plate)	Level of contamination
surgical department	2427	NA	S. epidermidis	> 500	2183.787561	High
		SDA	Yeast	1	4.367575122	Low
	2411	NA	S. epidermidis	154	672.6065688	High
			Aci. baumannii	123	537.21174	High
		SDA	Yeast	5	21.83787561	Low
medical laboratories	1108	NA	S. saprophyticus	> 500	2183.787561	High
			S. epidermidis	7	30.57302586	Low
	1117	NA	S. saprophyticus	46	200.9084556	Low
			S. epidermidis	26	113.5569532	Low
Daycare unit	502	NA	Ps. Luteola	> 500	2183.787561	High
			S. epidermidis	72	314.4654088	Intermediate
		SDA	Yeast	1	4.367575122	Low
	510	NA	photo. damselae	59	257.6869322	Low
			S. epidermidis	40	174.7030049	Low
		SDA	Yeast	1	4.367575122	Low
Staff department	Reception	NA	S. epidermidis	50	218.3787561	Low
			Bacilli	67	292.6275332	Low
		SDA	Yeast	2	8.735150245	Low
	G724	NA	S. epidermidis	95	414.9196366	Intermediate
Emergency department	Reception	NA	S. epidermidis	39	170.3354298	Low
			S. aureus	1	4.367575122	Low
		SDA	Yeast	2	8.735150245	Low
	Patient room	NA	Aci. baumannii	25	109.1893781	Low

Sampling Location	Room Number	Media used for sampling	Findings	Colony-forming units/plate	Total Microbial Load (CFU/plate)	Level of contamination
			S. epidermidis	11	48.04332635	Low
		SDA	Yeast	3	13.10272537	Low
Outdoor	At the clinical training window	NA	Aer. hydrophila gr.2	91	397.4493361	Intermediate
			Aci. baumannii	30	131.0272537	Low
		SDA	Yeast	6	26.20545073	Low
	At the emergency door	NA	Aci. baumannii	154	672.6065688	High
			S. saprophyticus	72	314.4654088	Intermediate
			v. fluvialis	5	21.83787561	Low
		SDA	Yeast	9	39.3081761	Low

Discussion

Many factors were studied including outdoor activity, location of the activity in the health care facility, temperatures, and percentage of humidity. Outdoor air pollution may be due to traffic and combustion processes that penetrate the indoor air as well, especially in Rafidia Governmental Surgical Hospital, which is closer to traffic. Recent evidence indicates that Vehicle emissions, particularly automobile emissions, are responsible for almost two-thirds of air pollution in urban areas. The main pollutants generated by automobiles are harmful to both human health and the environment (Bhandarkar, 2013).

Indoor pollutant levels change from one place to the next depending on the type and number of activities conducted in each area. We can improve the IAQ by removing common indoor sources of air pollution, such as floor coverings, air filters used in supply, and personal computers (Wyon, 2004).

All the positive colonies were tested by several biochemical tests to confirm the identity of the bacteria, and according to the obtained results, in Rafidia Hospital, airborne microbes appeared in the following proportions: S. epidermidis (2651.1181 CFU/m^3), S. saprophyticus (685.7093 CFU/m^3), S. aureus (5380.853 CFU/M3), Aer. hydrophila gr.1 (2183.787561 CFU/m^3), Aci. baumannii (934.661076 CFU/m^3), Past. Pne/Mann. haem (397.4493361 CFU/m^3), ser. rubidaea(428.022362 CFU/m^3), bacilli (13.10273 CFU/^{3}), and yeast (192.1733 CFU/m^3). So, predominant microbe was S. aureus.

In NNUH, microbes appeared in the following proportions: S. epidermidis (4341.369671 CFU/m^3), S. saprophyticus (2699.161425 CFU/m^3), S. aureus (4.367575122 CFU/m^3), Aer. hydrophila gr.2 (397.4493361

CFU/m^3), Aci. baumannii (1450.034941 CFU/m^3), v. fluvialis (21.83787561 CFU/m^3), Ps. Luteola (2183.787561 CFU/m^3), photo. damselae (257.6869322CFU/m^3), bacilli (292.6275332 CFU/m^3), and yeast (131.0272537 CFU/m^3). So, predominant microbe was S. epidermidis.

So, the level of airborne microbial pollutants in Rafidia Governmental Surgical Hospital appeared in greater proportions than in NNUH, as it reached in Rafidia Governmental Surgical Hospital (12430.1188 CFU/m^3), while in NNUH (11779.3501 CFU/m^3).

Furthermore, factors such as humidity, temperature, and density of people were tested against the concentration of fungal spores and airborne bacteria, As the growth rate of bacteria and fungi increased with the increase in humidity and temperature (Dannemiller, Weschler, & Peccia, 2017).

According to previous research, indoor air quality is influenced by several factors, including the number of people present, the level of hygiene, the quality of the hospital system, and the mechanical movement within the confined space. Whereas, the quantity of bacteria in restricted places or spaces with a large number of employees, patients, and their families is substantially higher than in private locations for a limited number of employees or patients, such as private rooms for employees or a room with a small number of patients. This is supported by the findings of our research. (Luksamijarulkul et al., 2019)

Besides, compared with previous studies (2016 study), we noted that the infection levels before the Corona pandemic were relatively high; As it's airborne microbes in the surgical department (the joint section with our study) consist of S. aureus at a rate of 33 CFU/m3, coagulase-negative staph (CoNS) at a rate of 2173 CFU/m3, bacilli at a rate of 10 CFU/m3, and yeast at a rate of 168 CFU/m3. While the values of this study were as follows: 0 CFU/m3 of S. aureus, 436 CFU/m3 of CoNS, 0 CFU/m3 of bacilli, and 11 CFU/m3 of yeast

Conclusions And Recommendation

Based on the comparison between the result of the two hospitals, it's viewed that Rafidia Governmental Surgical Hospital is the most contaminated with airborne bacteria and fungi; Because it is close to traffic congestion and the small size of its facilities compared to NNUH.

As for the difference in the average levels of microbes before and during the Corona pandemic, we noticed a noticeable decline during the pandemic in hospitals, especially. In the essence of speech, there is a noticeable commitment by the hospital, staff, and patients to the public health and safety guidelines imposed by the MOH including the necessary sterilizations, wearing a mask, and maintaining social distancing.

Both hospitals were informed of their results for consideration, all results were satisfactory and we recommend that both hospitals maintain the level of cleanliness, sterilization and adhere to public health and safety guidelines.

Abbreviations

IAQ: indoor air quality.

NNUH: An-Najah National University Hospital.

JCI: Joint Commission International.

FMHS: Faculty of Medicine and Health Science.

MOH: Ministry Of Health.

CFU: Colony Forming Unit.

ICUs: Intensive Care Units.

OPD's: Out-Patient Departments.

CoNS: Coagulase-Negative Staphylococci.

NR: Neonatal Room.

SOR: Surgical Operation Room.

NA: Nutrient Agar.

SDA: Sabouraud Dextrose Agar.

BA: Blood Agar.

MA: Macconkey Agar.

API: Analytical Profile Index.

IRB: Institutional Review Board.

Declarations

Ethics approval and consent to participate

To carry out this study, all methods were carried out in accordance with relevant guidelines and regulations. Approvals from the Office of the Institutional Review Board (IRB) of An-Najah National University, MOH, NNUH, and Rafidia Governmental Surgical Hospital were provided. Informed consent have been fulfilled as participation in this study was voluntary. Information about the aim of this study was provided to the participants. They also could withdraw from the study at any time without any punishment. It was confirmed that strict privacy was maintained all the time of the study period, so the questionnaire was recorded via using serial numbers

Consent for publication

'Not applicable'

Availability of data and materials

The datasets of the current study are available for the public from the corresponding author. As it is listed in tables in the results field

Competing interests

The authors declare that they have no competing interests.

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Contributions

All authors listed have contributed to the work and approved it for publication. The authors have worked in an organized manner. W.M has supervised the work, designed the study, communicated with the key persons, and reviewed the final manuscript for approval.

All authors wrote the manuscript. A.D and T.H have collected the data from NNUH. T.A and R.S have collected the data from Rafidia Governmental Surgical Hospital. A.D has calculated the CFU/m3 for each plate and prepared all tables. R.S has checked the dictation of the article. T.A has coordinated and included the references. T.H has reviewed the data. The authors read and approved the final manuscript.

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