J. Egypt. Soc. Parasitol. (JESP), 44(3), 2014: 749- 759

AIR QUALITY IN AIN SHAMS UNIVERSITY SURGERY HOSPITAL

By
M.Y. EL AWADY[1], A.T. ABD EL RAHMAN[2], L.S. AL BAGOURY[1] AND I.M. MOSSAD[1]

Department of Community, Environmental, and Occupational Medicine[1], and Department of Microbiology and Immunology[2], Faculty of Medicine, Ain Shams University, Cairo 11566, Egypt

Abstract

Through air sampling, it was possible to evaluate microbial contamination in environments at high risk of infection, and to check the efficiency of ventilation system and the medical team's hygiene procedures. This study measured the concentration of particulate matter (PM) 2.5 or less microns and microbiological organisms in operating rooms (OR), intensive care units (ICU) and emergency rooms (ER) in Ain Shams University Surgery Hospital, and to assess ventilation characteristics in operating rooms in the hospital.

The passive air sampling was done from ICUs, ORs, and ERs in Ain Shams University Surgery Hospital. Also for each operating room, an observational checklist was done to record other factors that may affect air quality in the room. The evaluated air quality indices were: suspended (PM) 2.5 micrometer or less, culture media and microbial identification of bacteria and fungi, and temperature and relative humidity. The results showed that the highest mean found for bacterial (105.70±30.49) and fungi concentration (7.50±5.30) was in ER. The three settings did not differ statistically as regard levels of PM 2.5, temperature, and relative humidity. A positive correlation exits between bacteria and fungi concentration on one hand and relative humidity on the other. Diphteroid, CONS, MRSA, *S. aureus*, and Anthracoid were the most frequent isolated bacterial types, while *Penicillium* and *Asperigillus fumigatus* were the most frequent isolated fungi. In operating rooms, the percent of unmasked persons present and the temperature positively influence the bacterial count, while ventilation condition is negatively influencing fungi count, and the number of persons present in the operating room positively affects the PM level.

Key words: Egypt, University Hospital, Air pollution, Microbes

Introduction

The surgical-site infection is a serious complication of surgery. Microbiological contamination of air in the operating room is generally considered to be one of the risk factors for surgical site infections in clean surgery (Landrin *et al,* 2005).

The air borne route of infection requires infectious agents that are either droplet nuclei or particulate matter (dust) which act as a harbor for micro-organisms. The dirt particles measuring 5 microns and less can stay airborne indefinitely and travel hundreds of feet from its source by natural air currents or ventilation systems then settle down in an open wound (Mills, 2003). Aerosols are solid and liquid particles, and microorganisms dispersed in the air. The aerosols sources could be introduced from outside when filters are not efficient, or because of air infiltration due to improper room pressurization. In operating rooms, however the main sources which have an indoor origin are the patient, the surgical team and equipment (Melhado *et al,* 2006).

Several potential nosocomial pathogens (e.g., *Staphylococcus aureus, S. epidermidis*) and other drug-resistant isolates have been frequently recovered from areas adjacent to the surgical field (Edmiston *et al,* 1999). The periprosthetic infection rates correlate with the number of airborne bacteria within the wound (Gosden *et al,* 1998), and that in hospital environments, the use of air filtration through a high-efficiency particulate air (HEPA) system completely eliminated invasive pulmonary aspergillosis in immune-compromised patients (Oren *et al,* 2001).

Thus, to prevent surgical site infection, airborne microbial concentration in operating theaters must be reduced. Maintaining a high degree of air cleanliness in the operating theatres and in other clean zones in operating suites is extremely important for patients with debilitated immune systems, who are prone to infection as well as for healthcare personnel (CDC, 2003).

Factors influencing airborne contamination in operating theatres are: type of surgery, quality of air provided, rate of air exchange, number of persons present in operating theatre, movement of operating room personnel, level of compliance with infection control practices, quality of staff clothing, and quality of cleaning process (WHO, 2002). The use of diathermia increases the level of small particles in the air, and this may influence the air quality in the operating theatres (Andersen *et al,* 1998).

For minimizing airborne particles, air must be circulated into the room with a velocity of at least 0.25 m/sec through a (HEPA) filter, which excludes particulate matter of defined size. If particles 0.3 microns in diameter and larger are removed, the air entering the room will be essentially clean and free of bacterial contaminants (WHO, 2002).

In intensive care units, laminar flow units have been used in the treatment of immuno-suppressed patients. For operating theatres, a unidirectional clean airflow system with a minimum size of 9 m2 (3x3 m) and with an air speed of at least 0.25 m/s protects the operating field and the instrument table. This ensures instrument sterility throughout the surgical procedure (WHO, 2005).

Modern operating theatres have conventional plenum ventilation with filtered air where particles >/=5 micron are removed. For orthopaedic and other implant surgery, laminar-flow systems are used with (HEPA) filters where particles >/=0.3 micron are removed. The use of ultra-clean air has been shown to reduce infection rates significantly in orthopaedic implant surgery. Few countries have set bacterial threshold limits for conventionally ventilated operating rooms, although most recommend 20 air changes per hour to obtain 50-150 colony forming units/ m(3) of air. With the use of HEPA filters in operating theatre ventilation, there is a tendency to apply cleanroom techno-logy standards used in industry for hospitals (Dharan and Pittet, 2002).

Since operating theatres require high cleanliness of indoor air, they are classified as clean rooms on basis of the quantitative concentration of airborne dust particles and microorganisms (Charkowska, 2008). Although safe airborne bacterial limits, such as 10 CFU/ m3 and 180 CFU/m3 were proposed, no international consensus exists regarding tolerable microbial levels in operating theaters (Tang and Wan, 2013).

By air sampling, it was possible to evaluate environmental microbial contamination at infection high risk of. Besides, these controls can be used to check the efficiency of both the conditioned and controlled ventilation system (CCVS) and the team's hygiene procedures (Napoli *et al*, 2012). Periodic monitoring of ventilation system efficiency is needed to ensure optimal indoor air quality (Tang *et al,* 2009).

The study aimed to measure the concentration of particulate matter 2.5 or less microns and microbiological organisms in operating rooms (OR), intensive care units (ICU) and emergency rooms (ER) in Ain Shams University Surgery Hospital, and to assess ventilation characteristics in operating rooms in the hospital.

Materials and Methods

This study was conducted in Ain Shams University Surgery Hospital, Cairo, Egypt. The hospital has an average of 36,000 inpatient yearly, and containing 664 inpatient beds and 59 ICU beds. Air samples were taken from the following sites in the hospital: 4 intensive care units (ICU), 8 operating rooms (OR), and 5 emergency rooms (ER).

In operating rooms, two samples were taken each time, one when the room is resting (not operating) early in the morning at 8:00 am and another one when it was operating at 9:30 am. Each room was sampled for one hour and repeated for quality assurance.

During the sampling period, indoor air was conditioned but not heated. A ceiling-mounted high efficiency particulate air (HEPA)-filtered laminar air flow with 15 air changes per hour (ACH) supplied the operating theater area but in some rooms an additional conventional air conditioning system was added as the main HVAC (heating, ventilation, and air conditioning). The HEPA filters are changed annually and were last changed ten months before sampling. Also for each operating room, an observational checklist was done at operation time to record other factors that may affect air quality in the room which are: Room number, date of surgery, type of surgery whether it's clean or contaminated, number of persons inside OR, door opening, use of surgical instruments that produce smoke, number of unmasked surgical personnel, and ventilation condition.

At the ICU and ER one sample was taken during operation at 9:00 am for one hour and repeated for quality assurance. Both were supplied partially with conventional air conditioning and other parts central air conditioning system. Sometimes windows were opened in ICU with natural ventilation current.

All samples of air quality indices were repeated in a second round after two weeks during January and February 2014.

Air quality Monitoring: 1- Location: Settle plates and the particulate matter air samples were located next to patient bed and nearest ventilation vent in operating room and ICU (Cristina *et al,* 2012). As for the emergency room, since it has multiple beds and large surface area the locations included areas where there is little air movement i.e. dead spaces (Scottish Quality Assurance, 2004). 2- The evaluated air quality indices were a- Suspended Particulate Matter (PM) 2.5 micrometer or less. Levels were measured using a portable dust monitor (MiniVol Portable Air Sampler, Airmetrics, U.S.A.), In the PM 2.5 sampling mode, air is drawn through a particle size separator and then through a filter medium, b- Culture media and microbial identification of bacteria and fungi, c- Temperature and relative humidity (RH) using a digital thermometer and hygrometer (BT-2, China), and d- Microbial air sampling and culture technique: Passive sampling was performed to determine the Index of Microbial Air Contamination (IMA) (Placencia and Oxborrow, 1984). This index corresponds to the number of CFU counted on a Petri dish with a diameter of 9 cm placed according to the 1/1/1 scheme (for an hr, 1 m above the floor, about 1 m) away from walls or any major obstacles.

Nutrient agar (NA) (LABM Limited, Lancashire, UK), supplemented with 100 mg/L cyclohex-amide was used for the sampling and cultivation of bacteria (Obbard and Fang, 2003).

For isolation of fungi, Sabouraud dextrose agar (SDA) (LABM Limited, Lancashire, UK), supplemented with 10 mg/L chloramphenicol was used (Rainer *et al,* 2000). Blood agar (BA) supplemented with 5% sterile blood, NA and BA were incubated at 37°C for 48 h to allow the growth of aerobic bacteria, while SDA plates were incubated for up to 5 days at 25°C to allow the growth of fungal colonies.

Bacterial colonies were initially characterized by microscopic appearance and morphology and identified then by biochemical reaction tests. These tests include Catalase, Coagulase, Indole, Methyl-red and Voges-proskauer, fermentation of glucose, lactose, and mannitol, citrate utilization, gelatin hydrolysis, and starch hydrolysis. Blood Agar, MacConkey Agar, Mannitol Salt Agar, Eosin-Methylene Blue Agar and Muller Hinton were used for differentiation, performed according to Bergey's Manual of Systematic Bacteriology (Sneath *et al,* 1986)

A wet mount preparation of each fungal colony was prepared by using Lactophenol-cotton blue solution and examined microscopically. Identification of fungi was mainly based on growth colonies appearance, microscopic examination of the spore and hyphael characterstics of the stained preparations (Samson *et al,* 2002).

All laboratory tests were carried out at microbiology department in Faculty of Medicine, Ain Shams University, Cairo, Egypt.

Statistical Analysis: Data was processed and analyzed using SPSS version 20.0 (Statistical Package for Social Science) software. The results were analyzed in terms of descriptive statistics, and the relationships between variables were tested by univariate, correlation and linear regression analyses.

Ethical considerations: Ain Shams University Surgery Hospital administrative approval was obtained. The study protocol was submitted for approval from the ethical committee of Faculty of Medicine Ain Shams University.

Results

In the ICU, ER and OR there were differ statistically with significance as regard bacteria and fungi concentration (p-value 0.000 and 0.009 respectively) with highest mean seen in ER (105.70±30.49 and 7.50±5.30 colony count per Petri dish for bacteria and fungi concentrations respectively). On the other hand, the three settings do not differ statistically as regard PM 2.5, temperature, and relative humidity (Tab. 1). A significant positive correlation (Tab. 2) between bacterial concentration and three factors: fungi count, temperature, and relative humidity (p-value < 0.01). A significant positive correlation also exists between fungi concentration and relative humidity (p-value < 0.01).

Diphteroid and CONS represented nearly two thirds of the isolated bacteria in ICU, while Anthracoid and *S. aureus* are the main types isolated in ER (61.6%). MRSA and *S. aureus* represented 50% of the isolated bacteria in OR. Anthracoid and *S. aureus* was significantly higher in ER and OR than in ICU. The fungi was present in air samples of ICU, ER and OR, *Penicillium* (29.2, 28.6 & 31.6 % respectively) and *Asp. fumigatus* (20.8, 21.4 & 28.9 % respectively) were the most frequent types of fungi isolated. *Asp. cinnamon* was significantly higher in ICU than in ER or OR (Tab, 3; Figs. 1& 2).

Univariate analysis (Tab. 4) showed a significant positive relationship between patient's wound contaminations, percent of unmasked persons in the operating rooms, and increased temperature affecting bacterial count. Non-working ventilation and increased relative humidity are significant factors affecting fungi count. PM concentration is significantly higher when the operating room door is opened and when number of persons increased in the OR theatre.

According to multiple linear regression model in (Tab. 5), the percent of unmasked persons in the operating room and the temperature positively influence the bacterial count in the operating room air (this model explains 66.7% of the variability in the bacterial count), while ventilation condition is negatively influencing fungi count (this model explains 29.2% of the variability in fungi count). The number of persons in the operating room positively affects the PM concentration (this model explains 51% of the variability in the PM level).

Results

The results are shown in tables (1, 2, 3, 4 &5) and figures (1 & 2).

Table1: Air quality measurements in air samples in settings in Ain Shams University Surgery Hospital.

Variants	ICU (N=8)	ER (N=10)	OR (N=16)	F	p-value
Bacterial conc.*	34.38±21.68	105.70±30.49	34.13±24.28	27.28	0.000
Fungi conc.*	3.88±2.47	7.50±5.30	3.06±1.91	5.58	0.009
PM 2.5 (microgram/m³)	28.50±34.47	28.00±39.67	35.63±31.32	0.19	0.83
Temperature (Celsius)	24.04±1.23	24.99±0.64	24.48±1.39	1.472	0.245
RH (%)	58.13±3.91	62.80±3.55	58.31±6.54	2.631	0.088

ICU= intensive care unit, ER=emergency room, OR= operating room, F= ANOVA test. *concentration measured as colony count/ Petri dish.

Table 2: Correlation matrix of air quality measurements of air samples taken from settings in Ain Shams University Surgery Hospital.

		Bacterial conc.	Fungi conc.	PM 2.5	Temp.	RH
Bacterial conc.	Pearson Correlation	1	.507(*)	-.065	.576(*)	.457(*)
	p-value		.002	.717	.000	.007
	No.	34	34	34	34	34
Fungi conc.	Pearson Correlation	.507(*)	1	-.198	.027	.620(*)
	p-value	.002		.261	.880	.000
	No.	34	34	34	34	34
PM 2.5	Pearson Correlation	-.065	-.198	1	-.140	-.181
	p-value	.717	.261		.429	.305
	No.	34	34	34	34	34
Temp.	Pearson Correlation	.576(*)	.027	-.140	1	.250
	p-value	.000	.880	.429		.154
	No.	34	34	34	34	34
RH	Pearson Correlation	.457(*)	.620(*)	-.181	.250	1
	p-value	.007	.000	.305	.154	
	N.	34	34	34	34	34

* Correlation significant at 0.01 level (2-tailed).

Table 3: Types and frequency of bacteria and fungi isolated from air samples of settings in Ain Shams University Surgery Hospital.

	ICU (No. %)	ER (No. %)	OR (No. %)	Chi square	p-value
Bacteria					
Anthracoid	2(14.3)	8(30.8)	5(15.6)	7.48	0.02
Gram –ve bac.	0 (0)	0(0)	2(6.3)	2.39	0.30
CONS	4(28.6)	4(15.4)	2(6.3)	4.38	0.11
Diphteroid	6(42.9)	4(15.4)	7(21.9)	2.65	0.27
MRSA	2(14.3)	2(7.7)	8(25.0)	2.91	0.23
S. aureus	0(0)	8(30.8)	8(25.0)	11.52	0.00
Total (100%)	14	26	32		
Fungi					
Asp.fum	5(20.8)	6(21.4)	11(28.9)	0.23	0.89
Asp. flav	4(16.7)	4(14.3)	6(15.8)	0.35	0.84
Asp. niger	0(0)	4(14.3)	2(5.3)	5.44	0.07
Fusarium	2(8.3)	0(0)	3(7.9)	2.61	0.27
Lycthemia	4(16.7)	4(14.3)	3(7.9)	2.76	0.25
Penicillium	7(29.2)	8(28.6)	12(31.6)	0.51	0.77
Black pd	0(0)	2(7.1)	1(2.6)	2.46	0.29
Asp. cin	2(8.3)	0(0)	0(0)	6.91	0.03
Total (100%)	24	28	38		

Gram –ve bac. =Gram –ve bacillus, CONS= Coagulase negative staphylococcus, *S. aureus*= *Staphylococcus aureus*, MRSA= Methicillin-resistant *S. aureus*, Asp. fum= *Asperigillus fumigatus,* Asp.flav = *Asperigillus flavus*, Asp. niger=*Asperigillus niger*, Asp. cin= *Asp. cinnamon*, Lycthemia=Lycthymia cormbefera, Black pd=Black piedra.

Table 4: Univariate analysis for factors affecting microorganisms and PM 2.5 concentration in air samples of operating surgery rooms in Ain Shams University Surgery Hospital.

	Bacterial conc.	Fungi conc.	PM 2.5
Use of instruments that produce smoke			
Used	37.20±26.57	2.80±2.28	54.40±27.09
Not used	32.73±24.39	3.18±1.83	38.43±24.99
t-test	0.33	-0.36	1.72
p-value	0.75	0.73	0.11
Door			
Opened	34.60±28.40	2.00±2.00	62.40±36.18
Closed	33.91±23.70	3.55±1.75	23.45±20.56
t-test	0.05	-1.57	2.77
p-value	0.96	0.14	0.02*
Ventilation condition			
Not working	28.71±24.59	4.29±1.25	43.14±27.00
working	38.33±24.62	2.11±1.83	29.78±34.71
t-test	0.78	-2.68	-0.84
p-value	0.45	0.02*	0.42
Wound contamination			
Contaminated	50.00±22.08	2.67±2.07	39.00±38.94
Clean	24.60±21.04	3.30±1.89	33.60±27.93
t-test	-2.30	0.63	-0.32
p-value	0.04*	0.54	0.75
No. of persons in OR			
Pearson correlation	0.10	-0.13	0.73
p-value	0.72	0.63	0.001*
Percent of unmasked persons			
Pearson correlation	0.74	-0.04	0.07
p-value	0.001*	0.90	0.81
Temperature			
Pearson correlation	0.707	-0.227	-0.134
p-value	0.002*	0.398	0.620
Relative humidity			
Pearson correlation	0.453	0.563	-0.253
p-value	0.078	0.023*	0.345

*significance at p-value less than 0.05

Table 5: Multiple linear regression analysis of the factors affecting bacterial*, fungi**, and PM concentration*** in operating surgery rooms in Ain Shams University Surgery Hospital.

Model*	Beta	SE	95% CI	
			Lower Bound	Upper Bound
(Constant)	-183.20	69.40	-333.14	-33.27
Percent of unmasked persons	0.62	0.20	0.18	1.05
Temperature	8.15	2.93	1.81	14.49
Model**				
(Constant)	4.29	0.61	2.98	5.59
Ventilation condition	-2.18	0.81	-3.92	-0.43
Model***				
(Constant)	-68.44	26.28	-124.81	-12.07
No. of persons in OR	17.17	4.24	8.07	26.26

* adjusted R^2 = 0.667, ** adjusted R^2 = 0.292, & *** adjusted R^2 = 0.51

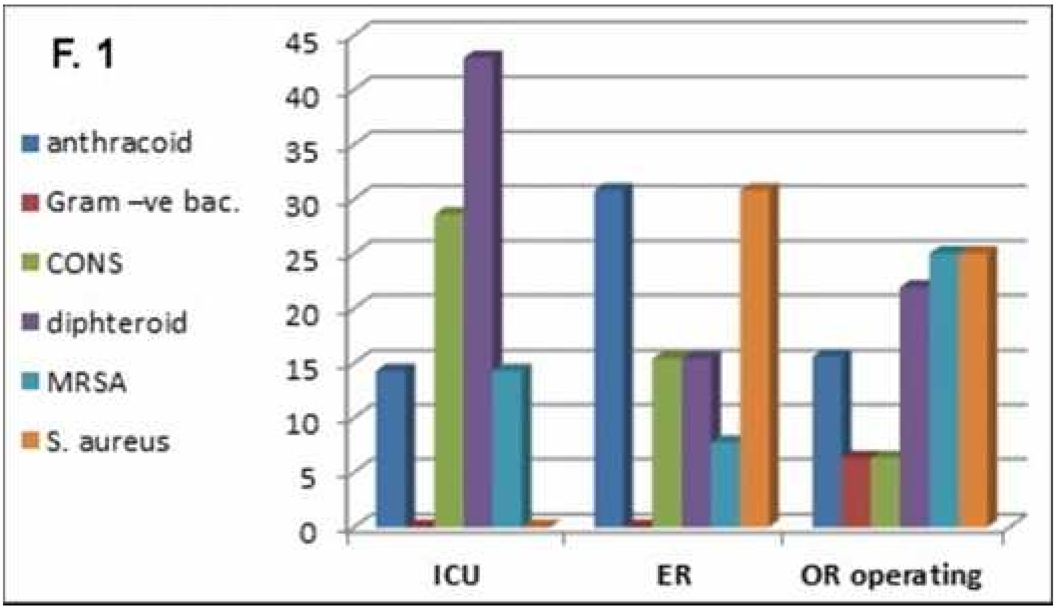

Fig.1: Percent distribution of bacterial types isolated from air samples of settings in Ain Shams University Surgery Hospital

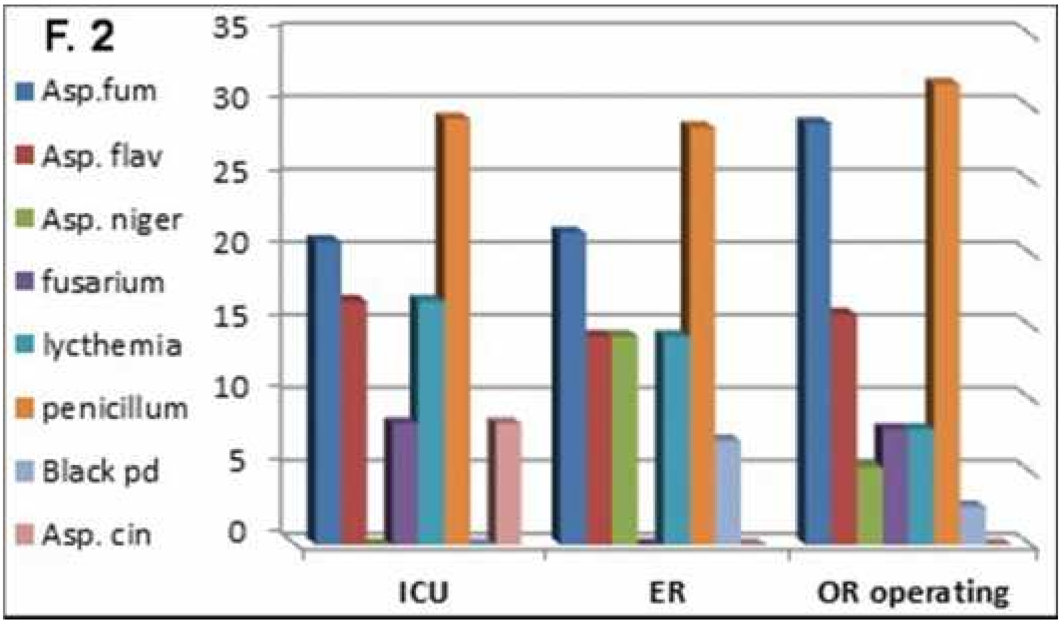

Fig. 2: Percent distribution of fungi types isolated from air samples of settings in Ain Shams University Surgery Hospital

Discussion

No doubt the present results agreed with those of Singh *et al.* (2013) in which higher bacterial contamination was found in air samples instead of surface or article sample, and the maximum growth of contaminated bacteria was observed in General Surgery ward. The place representing the higher risk of skin infections, boils, wound infections or abscesses.

By using passive air sampling technique to evaluate microbial contamination, results of the current study showed that all air samples from all areas in Ain Shams University Surgery Hospital were positive for growth of bacterial colonies. In Sudan, out of 79 samples that were collected from delivery rooms at different hospitals, 52 of them (63.3%) showed positive bacterial growth (Yagoub and El Agbash, 2010).

According to maximum acceptable levels of index of microbial contamination in environment at risk, the present recorded values were considered high in OR and ICU (34.13±24.28 and 34.38±21.68 respectively) as there mean exceeded the allowable 25 CFU/dish. Also, ER (105.70 ±30.49) exceeded the 50 CFU/dish limit for medium risk areas (Pasquarella *et al,* 2000).

In the present study, only one sampling point located nearly1 meter away from the surgical table (as recommended by the (Cristina *et al,* 2012) and, in this position, all samples from OR exceeded the limit values. Napoli *et al*. (2012) revealed that levels of recorded microbial contamination in operating rooms are influenced by external factors such as the point of collection in the operating room. In the light of this study sampling near the wound would have probably resulted in values more than those recorded in all plates of our study, showing that the situation would have been more critical. This confirms previous reports in which, using passive sampling method, higher microbial counts were found on settle plates in operating rooms nearer the wound than away from it (Friberg *et al,* 1999).

Regarding intensive care unit, bacterial concentration was found to be high as that reported by Li and Hou (2003), in the hospital operating rooms in Taipei, Taiwan, the concentration of airborne bacteria varied from 10 to 102 CFU/m^3. This might be correlated to the fact that both hospitals allow visitors to enter the ICU without any precautions. Patient visitation has a bad impact on the indoor climate in the ICU environment (Tang *et al,* 2009). The intensive care unit has to deal with critical cases and there must be sufficient strategies to reduce the microbial rates as much as possible to prevent occurrence of hospital acquired infections to patients and healthcare workers. This agreed with Krogulski (2008).

In the present study, the isolated bacteria were Diphteroid and CONS had the highest percentage in ICU while in ER the highest percent was for Anthracoid and Staph aureus. Both MRSA and *S. aureus* were the most frequent in OR. The presence of these pathogenic bacteria in air samples of OR increases the risk for patients undergoing surgical operations to acquire surgical site infections (Dharan and Pittet, 2002). Also, Gadallah *et al*. (2014) in Ain Shams University Surgery Hospital reported 8.5%, and that both MRSA and *S. aureus* were the commonest microorganisms involved. In Jordon Governmental Hospital, nine bacterial species were identified. *Staphylococcus aureus* (16.2%) and CONS (13%) were commonest organism isolated (Qudaiesat *et al,* 2009). In India the highest percentage of bacterial pathogens isolated was *S. aureus* and coagulase negative *Staphylococci* spp. (Singh *et al,* 2013). In Saudi Arabia University Hospital the predominant genera of airborne bacteria identified was *Staphylococcus* spp. 50% (El-Sharkawy and Noweir, 2012).

In this study, fungi was isolated from almost all samples of ICU, ER and OR with mean fungal colony count of ICU, ER, OR (3.88, 7.5, 3.06 respectively). This was higher than standards of IMA index that the allowable count is zero up to 2 colonies only (Pasquarella *et al,* 2000). The present isolated fungus was *Penicillium* followed by *Aspergillus fumigatus*, with a statistical significant difference between ICU, ER and OR as regards *Aspergillus cinnamon*. Air samples taken from a governmental hospital in Zarqa City in Jordon showed that OR and ICU fungal CFU/m3 air in morning sample was (28, & 36 respectively) which is considered a high colony count level as well (Qudiesat *et al,* 2009). In Saudi Arabia, *Aspergillus* spp., *Penicillium* spp., *Rhizopus* spp. and *Alternaria* spp. were isolated from the ER department has the highest concentrations of different fungal species (El-Sharkawy and Noweir, 2012). In contrast, in Italy fungi were isolated only during two separate surgical operations; the first operation revealed *Aspergillus* spp. and in the second revealed *Penicillium* spp. (Napoli *et al*, 2012).

The fact sheet of particulate matter air pollution and how it harms health use the mass concentration of PM 2.5 as an indicator of health risk. WHO air quality guidelines defined PM 2.5 standards by adding new and annual 24hr. PM2.5 standards at 10μg/m³ & 25g/m³, respectively (WHO, 2005). In the present study PM 2.5 concentration in all study settings was above WHO standard level with the highest mean in OR was 35.63±31.32 microgram/m³. In Saudi Arabia, El Sharkawy and Noweir (2012) found that levels of PM (both PM_{10} & TSP) were higher than the air quality guide (ER 210.24 microgram/m3, ICU 205.62 microgram/m3, OR 313.92 microgram/m3).

In this study, the airborne particle cleanliness of operating theatres was ISO 6 during operation because ISO 6 (Class 1,000) and above cleanrooms generally utilizes a non-unidirectional, or turbulent, airflow, which means the air is not regulated for direction and speed. This is similar to results of a study done in Finland. They studied air and surface hygiene in four Finnish operating theatres, the air cleanliness with laminar supply was found to be ISO class 6 due to control problems in the ventilation systems and the particle concentration during operations was quite high (Wirtanen *et al,* 2012)

The present results also revealed that there is a positive correlation between number of persons present inside OR and PM 2.5 level with (P= 0.001). An assessment of indoor PM 2.5 concentrations at a medical faculty in Turkey found that the room with 2 people working had higher levels of PM 2.5 than that with 3 persons, due to the working people moving in and outdoors (Yurtseven *et al,* 2012). Such particulates include the skin debris, with dimensions that vary from 2.5 to 20 μm, and which are constantly being released by both theatre staff and patients (Cristina *et al,* 2012). Also, the number of persons present influences the amount of movement taking place in the room, which tends to raise any dust that has already settled (Scaltriti *et al,* 2007).

In this study, temperature levels at ICU, ER and OR were (24.04, 24.99, 24.48°C respectively) while relative humidity were (58.13, 62.80, 58.31% respectively). Inside health care facilities, the temperature is affected by the outside temperature and effici-ency of mechanical ventilation system indoors (Godish, 2003). A significant positive correlation existed between relative humidity and fungi concentration (P=0.023). El Sharkawy and Noweir (2012) tested factors like humidity, temperature, and occupant density against the concentration of airborne fungal spores and MRSA, and showed that humidity affected the concentrations of airborne fungi. The frequent use of doors, the high respiration activity by the large number of visitors and patients, and the leaks in the ventilation system in some old parts of the hospital, tended to increase the humidity and affect the number of airborne fungi. Tang reported that the temperature and relative humidity suitable for the growth of fungi were 26°Celsius and 50-60%, respectively (Tang *et al,* 2009). This might explain the fact that almost all our samples were positive as regard fungi growth.

The American Society of Heating, Refrigeration, and Air-conditioning Engineers recommend acceptable ranges of temperature and percent relative humidity for comfort. The range 20-24°C in winter and 23-27°C in summer are acceptable, & 30-60% is acceptable for RH (ASHRAE, 1999). This means that the mean level of temperature and percent RH at this study were at the highest acceptable levels and that explains all positive cultures.

Conclusion

The outcome data showed that the concentration and the distribution of microbial organisms in the intensive care unit, emergency room and operating theaters, warrants attention from hospital infection control and environmental safety departments to reduce exposure risk of infection to surgical patients and healthcare workers. Cleaning and maintenance frequency for ventilation systems in operating theaters should be adjusted according to published universal guidelines. Further studies are required to identify potential hospital indoor air quality problems that result from healthcare procedures and equipments.

References

Andersen, BM, Røed, RT, Solheim, N, Levy, F, Bratteberg, A, *et al*, 1998: Air quality and microbiologic contamination in operating theatres, Tidsskr. Nor. Laegeforen. 118, 20: 3148-51.

ASHRAE, 1999: HVAC Applications, Fundamentals. 1st Edition, Atlanta: ASHRAE, Inc; American Society of Heating, Refrigerating and Air-Conditioning Engineers, USA.

CDC, 2003: Guidelines for Environmental Infection Control in health care facilities. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_hcf_03.pdf.

Charkowska, A, 2008: Ensuring Cleanliness in Operating Theatres *International* J. Occupat. Saf. Ergonom. 14, 4:447-53.

Cristina, ML, Spagnolo, AM, Sartini, M, Panatto, D, Gasparini, R, *et al*, 2012: Can particulate air sampling predict microbial load in operating theatres for arthroplasty? Plos One J. 10:e0052809.

Dharan. S, Pittet, D, 2002: Environmental controls in operating theatres. J. Hosp. Infect. 51, 2:79-84.

Edmiston, CEJr, Sinski, S, Seabrook, GR, Simons, D, Goheen, MP, 1999: Airborne particulates in the OR environment. AORN J. 69, 6:1169-77.

El-Sharkawy, MF, Noweir, MEH, 2012: Indoor air quality levels in a University Hospital in the Eastern Province of Saudi Arabia. J. Family Comm. Med. 21, 1:39-47.

Eray, Yurtseven, M, Erdogan, S, Ulus, T, Ulkualver, S, 2012: An assessment of indoor pm 2.5 concentrations at a medical faculty in Istanbul, Turkey. Environ. Protect. Kalliohaka Eng. 38, 1:34.

Friberg, B, Friberg, S, Burman, LG, 1999: Correlation between surface and air counts of particles carrying aerobic bacteria in operating rooms with turbulent ventilation: an experimental study. J. Hosp. Infect. 42:61-8.

Gadallah, MA, Aboul Foutouh, AM, Al Bagoury, LS, Bassim, HH, Al Gaafary, M M, 2014: Incidence and Risk Factors of Hospital Acquired Infections in Ain Shams University Hospital (In Press).

Godish, T, 2003: Air quality Boca Raton. 4th edition, Florida: Lewis Publishers.

Gosden, PE, MacGowan, AP, Bannister, GC, 1998: Importance of air quality and related factors in the prevention of infection in orthopaedic implantsurgery. J. Hosp. Infect. 39, 3:173-80.

Gun Wirtanen, Salme Nurmi , Tapio, Inga Mattila, Kimmo Heinonen,Seppo Enbom, Satu Salo, Hannu Salmela, 2012: Surface and air cleanliness in operating theatre. Euro. J, Parenteral & Pharmaceutical Sci, 17, 3:

Qudiesat, K, Abu-Elteen, K, Elkarmi, A, Hamad, M, Abussaud, M, 2009: Assessment of airborne pathogens in healthcare Settings. Afr. J. Microbiol. Res. 3, 2:1066-76.

Krogulski, A, 2008: Location and indoor air microbiological quality. Rocz. Panstw. Zakl. Hig. 59, 1:97-102.

Landrin, A, Bissery, A, Kac, G, 2005: Monitoring air sampling in operating theatres: can particle counting replace microbiological sampling. J. Hosp. Infect. 61, 1:27-9.

Li, CS, Hou, PA, 2003: Bioaerosol characteristics in hospital cleanrooms. Sci. Tot. Environ. 305:169-76.

Melhado, MA, Hensen, JL, Loomans, M, Forejt, L, 2006: Review of operating room ventilation standards. Proceed. 17th Inter. Air-Condition. Vent. Conf. Prague: STP- Society of Environmental Engineering.

Mills, F, 2003: Indoor air quality standards in hospitals (technology issues) chairman, construction and building services. Group Institute of Mechanical Engineers, USA.

Napoli, C, Marcotrigiano, V, Montagna, MT, 2012: Prevention of healthcare-associated infections: Which sampling method should be used to evaluate air bio-contamination in operating rooms? Epidemiol. Open Access J. 2, 2:1000e106.

Obbard, JP, Fang, LS, 2003: Airborne concentrations of bacteria in a hospital environment in Singapore. Water Air Soil Poll. 144: 333-41.

Oren, I, Haddad, N, Finkelstein, R, Rowe, JM, 2001: Invasive pulmonary aspergillosis in neutropenic patients during hospital construction: before and after chemoprophylaxis and institution of HEPA filters. Am. J. Hematol. 66, 4:257-62.

Pasquarella, C, Pitzurra, O, Savino, A, 2000: The index of microbial air contamination. J. Hosp. Infect. 46:241-56.

Placencia, AM, Oxborrow, GS, 1984: Use of the Reuter Centrifugal Air Sampler in Good Manufacturing Practices Investigations: Minneapolis Center for Microbiological Investigations, Minneapolis, FDA, Sterility Research Center, USA.

Rainer, J, Peintner, U, Pöder, R, 2000: Biodiversity and concentration of airborne fungi in a hospital environment. Mycopathol. 149:87-97.

Samson, RA, Hoekstra, ES, Frisvad, JC, Filtenborg, O, 2002: Introduction to Food-and Airborne Fungi. 6th Ed., Ponsen and Looyen, Wageningen, Netherlands.

Scaltriti, S, Cencetti, S, Rovesti, S, Marchesi, I, Bargellini, A, *et al*, 2007: Risk factors for particulate and microbial contamination of air in operating theatres. J. Hosp. Infect. 66:320-6.

Scottish quality assurance specialist interest group, 2004: Guidelines on Test Methods for Environmental Monitoring for Aseptic Dispensing Facilities, 2nd ed, http:// www.scribd.com/ doc /154909893/Environmental-Monitoring-for-Aseptic-Dispensing-Facilities

Singh, K, Dar, FA, Kishor, K, 2013L Bacterial contamination in operating theatres of district hospital. Innovative J. Med. Hlth. Sci. 3, 2:62-3

Sneath, PHA, Mair, NS, Sharpe, ME, Holt, JG, 1986: Bergen's Manual of Systema-tic Bacteriology 2, Baltimore, Williams and Wilkins.

Tang, CS, Chung, FF, Lin, MC, Wan, GH, 2009: Impact of patient visiting activities on indoor climate in a medical intensive care unit: a 1-year longitudinal study. Am. J. Infect Control 37, 3:183-8.

Tang, CS, Wan, GH, 2013: Air quality monitoring of the post-operative recovery room and locations surrounding operating theaters in a medical center in Taiwan. PLoS One 8, 4:e61093.

WHO, 2002: Prevention of hospital-acquired infections: A practical guide, 2nd ed., from http://www.WHO/CDS/CSR/EPH/ 2002.12.

WHO, 2005: Particulate Matter Air Pollution: How it Harms Health Fact sheet, retrieved October 23, <http://www.euro.who.int/document/ mediacentre/fs0405e.pdf>.

Yagoub, OS, El Agbash, A, 2010: Isolation of potential pathogenic bacteria from the air of hospital-delivery and nursing homes. J. Appl. Sci. 10, 11:1011-4.