HVAC STANDARDS FOR ACCEPTABLE THERMAL CONDITIONS IN THE HOSPITAL: A CASE STUDY

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Abstract

Hospitals and healthcare facilities are the most important application areas for heating, cooling, air conditioning and ventilation systems (HVAC). In this study, the applications of HVAC systems in critical area such as intensive care room and operating room are explained for the Qaladze hospital in Sulaymaniyah, Iraq. HVAC systems used in hospital have been examined, and solutions have been presented for the problems in terms of HVAC standards and energy. Indoor air temperature, indoor relative humidity, and supply air temperature measurements were made in different parts of the hospital and analyzed according to HVAC standards. The HVAC Standards were compared with each other. In general, it has been determined that the indoor air temperature and relative humidity are within the limits determined in the standards. Despite the changes in summer and winter seasons, the relative humidity was found to be around 30% and room temperatures around 24ºC. It was determined that the change in indoor temperature and relative humidity depends on the density in the hospital. All components of the air handling unit and HVAC systems should be constantly checked to improve the thermal conditions and indoor air quality in the various rooms in the hospital and to keep the parameters between the maximum and minimum values determined in the standards.

Keywords: Hospital, standards, HVAC, Thermal condition, Indoor Air Quality.

Özet

Hastaneler ve sağlık tesisleri ısıtma, soğutma, iklimlendirme ve havalandırma sistemleri (HVAC) için en önemli uygulama alanlarıdır. Bu çalışmada, yoğun bakım odası ve ameliyat odası gibi kritik alanlardaki ısıtma, soğutma, iklimlendirme ve havalandırma sistemlerinin uygulamaları, Irak Süleymaniye'deki Qaladze hastanesi için açıklanmıştır. Hastane iklimlendirilmesinde kullanılan HVAC sistemleri incelenmiş, standartlar ve enerji açısından tespit edilen problemlere çözümler sunulmuştur. Hastanenin değişik mahallerinde hava sıcaklığı, bağıl nem ve hava üfleme sıcaklıkları ölçümleri yapılmış ve ölçüm sonuçları standartlarla göre analiz edilmiştir. Ayrıca ısıtma, soğutma, iklimlendirme ve havalandırma sistemlerinin standartları birbiriyle karşılaştırılmıştır. Genelde iç ortamdaki sıcaklık ve bağıl nem değerleri standartlarda belirlenen sınırlar arasında olduğu tespit edilmiştir. Yaz ve kış mevsiminde değişmesine rağmen ölçüm sonuçlarına göre bağıl nemin ortalama %30 ve oda iç hava sıcaklıklarının ise 24ºC civarında olduğu görülmüştür. İç ortamlardaki hava sıcaklığı ve bağıl nemdeki değişimin hastanedeki yoğunluğa bağlı olduğu belirlenmiştir. Hastanedeki değişik odalardaki iç hava kalitesini ve ısıl koşullarını iyileştirmek ve parametrelerin standartlardaki maksimum ve minimum değerler arasında kalmasını sağlamak için klima

santrali ve HVAC sistemlerinin tüm bileşenlerinin sürekli kontrol edilmesi gerektiği görülmüştür.

Anahtar Kelimeler: Hastane, Standartlar, Termal durum, İklimlendirme, İç Hava Kalitesi.

1. INTRODUCTION

HVAC systems in the hospital are very demanding and play a determinant role in indoor environmental quality (IEQ). Also, energy efficiency in the HVAC system is required to affect the supply of air system and indoor air quality (IAQ), with increasing the effectiveness of ventilation to improving thermal comfort in hospitals. The thermal comfort to occupant comfort is acceptable ranges for temperature and humidity in the spaces of the hospital. Also, in hospitals, the amount of energy is required to properly all parameters when usage in air-conditioning must be according to standards in the world. Commonly air conditioning and ventilation are used to control of parameters of the hospital. Ventilation requirements and optional points are comparatively easy to achieve the perfect room air distribution and room conditions. The room condition was a general guide 80% of the occupant office spaces and thermal environments over a wide range of the parameters (Rock, 2006; Rock, 2002).

IAQ is the process of air comfort that gives in every system and does not cause negative health effects or disease in the hospitals. Also, IAQ is used to control (i.e. protects to airborne hazards such as tuberculosis bacteria and other infectious or chemical agents like anesthetic gases and pharmaceuticals that may become airborne during operation) and parameters (i.e. temperature, humidity, and air velocity) were to maintain indoor comfort conditions. The parameters for energy conservation must not adversely affect the patient's health, safety or accepted personal comfort levels of air in hospitals (ASHRAE, 1999a). The air in the hospital must be aseptic, at a constant temperature and humidity, and have relatively low velocity. The proper air for indoor comfort conditions (thermal, visual, and acoustical) and IAQ should be suitable environments of the hospitals especially in the operating room (OR) (ASHRAE, 2011). Air distribution inside of the hospital especially in the (OR) was to protect the patient and medical staff while maintaining occupant comfort and not affecting surgical tasks (Karimipanah, 2008; VDI, 2004).

The HVAC systems must be very careful about the selection to correct devices and compliance with related standards. Therefore, the HVAC system should be given hygienic air conditioning in the hospital building in terms of health and comfort conditions because in the hospital air must be fresh 100%. The air of the hospital must be aseptic to low velocity, constant temperature, and relative humidity, therefore the recommendation values must be accepted under the standards and guidelines. HVAC systems for comfort conditions were focused on the increasing or decreasing of parameters, such as temperature, relative humidity, the velocity of air, etc. which of them are used to optimum work of HVAC system in the hospitals.

1.1. Importance of Ventilation and Design Criteria for Sterile Spaces in Hospital

Ventilation is considered a significant factor for IAQ in the hospital. Also, ventilation is used extensively in all types of healthcare locations to provide a safe and comfortable and safe environment for patients and medical staff in the hospital. More specialization of ventilation can be provided to primary patient treatment areas such as isolation units and critical areas in the operating room (Mendell et al., 2008).

1.1.1. Design Conception and Criteria

Criteria for HVAC design in sterile rooms of hospitals have indoor air parameters such as temperature, room pressure, stage of filtration, humidity, and fresh air change rates. The effects of parameters are mentioned to design criteria of the infection control and thermal comfort in the hospital. The design criteria of HVAC systems are focus on three parameters for a comfortable indoor condition such as temperature, relative humidity, fresh air rate (Chengqin et al., 2002).

1.1.2. Surgery Rooms and Critical Care

All areas of the hospital must be more careful to control aseptic conditions, especially in the surgical suite. HVAC systems are used to serving conditions into operating rooms, including cystoscopic and fracture rooms, that require careful design to minimize the attention of airborne organisms (ACS 2000).

Class A surgery: is involved minor surgical procedures. Class B surgery: is provided minor or major surgical procedures. Class C surgery: is involved major surgical procedures.

1.1.3. Sterile Spaces in Hospital Hygiene

There are many have various risks of sterile spaces in hospital hygiene and many differential spaces are required a high level of hygiene in the hospital. According to the standard of DIN 1946-4 can be classified the spaces into two groups Class I, and Class II, high or very high need of hygiene, and normal levels of hygiene, respectively (ASHRAE, 2003).

1.1.3.1. Operating Site of the Hospital

The operating site is considering a special space department for a surgical procedure in the hospitals. Also, the operating site is a space within a hospital where the surgical operations carried out in an aseptic spaces environment and so consist of:

1.1.3.1.1. Operating Room

The operating room is the important space of the hospital and the levels of hygiene should be very high because the surgical procedure is carried out inside it. Also, OP rooms are one of the most significant of the operating site because most standards and guidelines are given information about it (ASHRAE, 2003).

Figure 1.1. Operating room (Qaladze Hospital, 2010).

1.1.3.1.2. Pre and Post Operative Recovery Rooms

Pre and Post, Operative Recovery rooms are used to combination with OP rooms during surgical producer. In this room, patients may be involved effects of anesthesia due to transmigration the first to second spaces of medication (ASHRAE, 2003).

Figure 1.2. Pre and Post OP room (Qaladze Hospital, 2010).

1.1.3.1.3. Soiled and Sterile Equipment Rooms

The soiled equipment room is used to composed and stored, and returnable equipment sending for cleaning by sterilization. The levels of hygiene in the sterile equipment room should be equal to or higher than the operating room.

1.1.3.2. Delivery Room

The delivery room is identical space to a general operating room when used for cesarean deliveries and breech birth. The types of delivery rooms are used normal surgical procedures, therefore the levels of hygiene should be high in the room (ASHRAE, 2003).

Figure 3.1. Delivery Room. (Qaladze Hospital, 2010).

1.1.3.4. Intensive Care Unit Room (ICU)

The ICU rooms are spaces where patients stay 24 h continuously and necessary for life-support patients of the hospital. ICU room has more types each of them used to a different purpose such as surgical intensive care, cardiac care unit, medical intensive care, post-anesthesia care, burn and wound intensive care, and neurological intensive care. The effects of HVAC system may differ according to types of ICU rooms for example in the burn intensive care unit needed high levels of hygiene and RH.

Figure 3.2. Intensive Care Unit (Qaladze Hospital, 2010).

1.1.3.5 Central Sterile Services

The central sterile services are the department liable for some cases of serve equipment of the sterile delivery room. Also, the central sterile department is used to cleaning prepare instruments, equipment while used in surgical procedures, delivery, and emergency care. Besides, in the central sterile equipment storage, the levels of hygiene must be higher than the OP rooms. This room should be positively pressurized to the neighboring spaces (ASHRAE, 2003).

Figure 3.3. Central sterile services storage (Qaladze hospital).

2. MATERIAL AND METHOD

The quality of HVAC equipment should be provided with a suitable environment for the patients, hospital staff, and employees according to the function of the hospital. The functions of the hospital for indoor comfort conditions depended on the design criteria of the HVAC system for accepted the levels of the personal condition of the room patients. The levels maintained to design criteria play a major role in the hospital hygiene of the environment as can directly affect the validation of parameters.

2.1. Parameters of Ventilation for Sterile Spaces in Hospitals

The HVAC system must provide to prevented air pollute virtually used by parameters. Therefore, the design criteria of the HVAC system must be used parameters under desire code standards and guidelines.

2.1.1. Room Temperature

The room temperature directly affects the thermal comfort of the medical staff and patients of the hospital. Thermal comfort is felt especially in the OP room because the medical staff wear garments and work under high radiant lighting. Also, the levels of room temperature should be controlled individually for each of the OP rooms and delivery rooms of the hospital (AIA, 2006). Average values for relative humidity ranges between 18-26°C according to more standards and guidelines (ASHRAE,2003)

2.1.2. Relative Humidity

Same as room temperature, the relative humidity is acted on thermal comfort for the patients and the medical staff of the hospital. The levels of relative humidity are very important during the cooling process of air should be controlled. Consequently, low levels of relative humidity

can also be acted on the patient wound especially during surgery producer. Besides low levels of relative humidity may require therefore the microbial can not grow (ASHRARE, 2011). Average values for relative humidity ranges between 30% to 60% according to more standards and guidelines.

2.1.3. Room Filtration

The air in the hospital must be fresh 100% of the hospital, therefore all rooms should be used filtration stages of the hospital. The sterile space in the hospital is closed environments since the particle concentration transported easily due to mechanical ventilation of air in the hospitals. To prevent the particle concentration, the air supply should be filtered appropriately along with the particle transportation in the sterile space of the hospital (ASHRAE, 2003).

2.1.4. Air Velocity and Air Distribution of the Room

The air velocity is a significant reason for the air distribution, and important for sterile spaces due to the influence on the thermal comfort patient and medical staff in the rooms. The applications of air distribution are mentioned to the filtration of air supply near the door and exhaust near the patient bed of the room. Therefore, the supply air should be above from the patient bed and exhaust near the door (ASHRAE, 2003). The levels of air velocity should be decreased because more effective waste anesthetic gases removed to the exhaust air in the rooms (Melhado, et al., 2005).

2.1.5. Pressurization of the Room

Pressurization is required to a specific room in a hospital usually expert under most codes by providing differential airflow rates of exhaust, supply, and return air. There are two kinds of room differential pressure, positive and negative pressure rooms. The pressure difference between the spaces required to maintain stability constant under standards and guidelines. The air of the room is considered by a positive pressurized, the room air should be the supply air volumetric flow rate into the room is more than the sum of return and exhaust air volumetric flow rates out of the room. In addition, the negative pressurized room should be the supply air volumetric flow rate is less than the sum of exhaust and return air of the room. Generally, the pressure differential in the patient room is 50 to 100cfm [24-47 L/s], and for a normal room, 5% to 10% supply flow should be lager the rooms. The room differential pressure must be high enough and can measure to control typical test and balance equipment with normal range sensing (ASHRAE, 2010a).

2.1.6. Total and Fresh Air Change of the Room

The total and fresh air change rates are significant to conserve the requirement of the sterile spaces in the hospital. Fresh air in the hospital must be 100% fresh air filtered by mechanically supplied air when taking into the rooms. The supply of fresh air may create problems by increasing the amount of oxygen and chemical gas diluting both of them cause of the raising of particles in the room air of the hospital. Exhaust and return openings should be kept that the levels of area and clear from any obstructions, especially that one near the floor level (Memarzadeh, 2002).

2.1.7. Air Movement

The hospital environment has more effects on normal patient care such as bacterial counts were by airflow in the hallway. Unwanted airflow is difficult to controlling between the rooms and floors due to open the door, movement of medical staff, temperature differentials, etc. Specialization of patient care areas should be appropriate ventilation to control the air quality of the hospital. Sometimes in the noncritical patient care, areas and medical staff may be used a variable air volume (VAV). VAV systems can be controlled pressure relationships and minimum ventilate for exhaust and return air under codes in the hospital (Lewis, 1988).

2.2. Standards of IAQ and Thermal Conditions for Hospitals

Many countries have norms, codes of building, standards, and guidelines, which are changing to the temperature, humidity, airflows, and pressure each of them used in thermal comfort for the hospital rooms. The parameters for thermal comfort condition according to standards and guidelines are given in the tables below.

2.2.1. Operating Room (OP)

The operating room is classified by two Classes according to DIN standard 1946-4 of hygiene needs of the surgical site. Class I and Class II, are used to levels of hygiene in the OP rooms (DIFN, 1999). According to ASHRAE and AIA, ORs are divided into three groups as Class A, B, and C as seen Table (2.1) (AIA, 2006; ASHRAE, 2003). Brazilian standard NBR specified a general determination and cesarean for the OP rooms (Melhado et al., 2005). Consequently, Australian Standards and Guidelines are similarly classified as of DIN 1946-4, where Option 1 is equal to Class Ia, and Option 2 is also equal to Class Ib.

2.2.2. Pre-OP and Post-OP Rooms

The information about the design parameters of the HVAC system for the pre and post OP room as seen in Table (2.2). The recommended value for all parameters can be found during the work HVAC system for the pre and post OP room. A comparison among the standards can reveal the work of all parameters of the HVAC system in the buildings.

2.2.3. Delivery Room

Design criteria for the delivery room should be a confirm condition, therefore the recommended value for design parameters of HVAC system should be indicated briefly of the delivery room accordance with the standards as seen in Table (2.3).

2.2.4. Intensive Care Unit (ICU) Room

Design criteria for the ICU room are very important because the patient may stay 24 h in the hospital. The hospitals have more different types of ICU room therefore design parameters may be taken different values as presents in accordance with the different aims of the references.

2.2.5. Central Sterile Services Department (CSSD)

The central sterile service department is a very important part of the health care places of the hospital. Recommendation value for all parameters should be desired according to standards and guidelines of the CSSD rooms as seen in Table (2.5).

Table 2.1. Recommended values for HVAC design parameters of the operating room according to standards and guidelines.

References	Operation of room type	Temperature ºC	Relative Humidity %	Filtration	Air velocity m/s	Air distribution	Pressure	Pressure difference	Out door ACH	Total ACH
ASHRAE	Class A Class B Class C	18-26	30-60	MERV 7/8/14/15-17 MERV 7/8/14/15-17 MERV 7/8/14/15-17	0.25-0.45	Laminar	P	2.5-7.5 Pa/ 35-45 L/s excess supply	5*/15**/ 15(lt/s)/ person	25*/15**
AIA	Class A Class B Class C	20-23	30-60	N/D	N/D	Laminar	p	2.5 pa	3	15
DIN	Class Ia Class Ib	19-26	30-60	F5-F7-H13 F5-F7-H13	N/D	Lamina/ Turbulent	P	20 m^3/h excess supply	1200 m^3/h	2400 m^3/h
CBZ	N/D	18-24	N/D	F5-F7-F9-H13	N/D	Laminar	P	N/D	N/D	N/D
VDI	N/D	18-24	30-50	F5/F6/F7-F9-H13	0.20	Laminar	P	N/D	N/D	N/D
NBR	General Cesarean	19-24 22-26	45-60	G2-F2-A3 N/A	N/A	N/A	P	N/A	N/A	N/A

Table 2.2. Recommended values for HVAC design parameters of the intensive care unit (ICU) room according to standards and guidelines.

References	Operation of room type	Temperature ºC	Relative humidity %	Pressure	Pressure difference	Filtration	Air velocity m/s	Air distribution	Out door ACH	Total ACH
ASHRAE	General	21-24	30-60	N/D	N/D	N/D	N/D		2	6
	Newborn	22-26	30-60	N/D	N/D	N/D	<0.25 m/s @ isolate level	Laminar	2	6
	Burn	N/D	40-60	P	N/D	HEPA	0.25 m/s @ Bed level		2	6
AIA	General	21-24	30-60	N/D	N/D	N/D	N/D	N/D	2	6
	Newborn	22-26	30-60	N/D	N/D	N/D	N/D	N/D	2	6
DIN	Infection	24-26	N/D	P	N/D	F5/F7-H13	N/D	N/D	30 $m^3/m^2.h$	N/D
VID	General	N/D	N/D	P	N/D	F9	N/D	N/D	100 m^3/h/ person	N/D

* Recommended of outdoor and Total ACH values for return air system.
** Recommended total ACH for 100% fresh air systems.
N/A: Not Available
N/D: Not Defined

Table 2.3. Recommended values for HVAC design parameters of the delivery rooms according to standards and guidelines.

References	Temperature ºC	Relative humidity %	Pressure	Pressure difference	Filtration	Air velocity m/s	Air distribution	Outdoor ACH	Total ACH
ASHRAE	20-24	30-60	P	N/D	N/D	N/D	N/D	5*/15**	25*/15**
AIA	20-23	30-60	P	N/D	N/D	N/D	N/D	3	15
DIN	min 24	N/D	N/D	N/D	F5-F7-H13	N/D	N/D	15 $m^3/m^2.h$	N/D
PHG	N/D	N/D	N/D	N/D	See Text	N/D	N/D	20 L/s/person or 2	10
NBR	22-26	45-60	P	N/A	N/A	N/A	N/A	N/A	N/A

Table 2.4. Recommended values for HVAC design parameters of the intensive care unit (ICU) room according to standards and guidelines.

References	Operation of room type	Temperature ºC	Relative humidity %	Pressure	Pressure difference	Filtration	Air velocity m/s	Air distribution	Out door ACH	Total ACH
ASHRAE	General	21-24	30-60	N/D	N/D	N/D	N/D	Laminar	2	6
	Newborn	22-26	30-60	N/D	N/D	N/D	<0.25 m/s @ isolate level		2	6
	Burn	N/D	40-60	P	N/D	HEPA	0.25 m/s @ Bed level		2	6
AIA	General	21-24	30-60	N/D	N/D	N/D	N/D	N/D	2	6
	Newborn	22-26	30-60	N/D	N/D	N/D	N/D	N/D	2	6
DIN	Infection	24-26	N/D	P	N/D	F5/F7-H13	N/D	N/D	30 $m^3/m^2.h$	N/D
VDI	General	N/D	N/D	P	N/D	F9	N/D	N/D	100 m^3/h/ person	N/D

Table 2.5. Recommended values for design parameters of HVAC system of the central sterile service and sterile equipment store.

References	Room Type	Temperature ºC	Relative humidity %	Pressure	Pressure difference	Filtration	Air velocity m/s	Air distribution	Out door ACH	Total ACH
ASHRAE	Soiled Eqpt Room	22-25	30-60	N	N/D	N/D	N/D	N/D	2	6
	Sterile Eqpt Room			P		MERV 8-15			2	4
	Sterile Work Room			P		MERV 8-15			2	4
AIA	Soiled Eqpt Room	20-23	N/D	N	N/D	N/D	N/D	N/D	N/D	6
	Sterile Eqpt Room	24	30-60	P						4
	Sterile Work Room	N/D	max 70	P						4
DIN	Sterile Eqpt Room	22-26	N/D	P	N/D	F5-F7-H13	N/D	N/D	15 $m^3/m^2.h$	N/D
PHG	N/D	N/D	N/D	P	N/D	See Text	N/D	N/D	N/D	10
VDI	N/D	N/D	N/D	P	N/D	F7-F9-H10/H11	N/D	N/D	N/D	N/D

ASHRAE: ASHRAE Standard, 2003
AIA: ASHRAE Guideline, 2006
DIN: Germany Standard, 1999
CBZ: Netherlands Guideline (Melhado, et al., 2005)
VDI: Germany Guideline, 2004
NBR: Brazilian Standard (Melhado, et al., 2005)
PHG: Australian Guideline, 1999

3. RESULT AND DISCUSSION

3.1. Thermal Comfort for Acceptable Room Condition in the Hospital

Knowing that working from all the hospitals in the world are maintained 24 hours periodically. In the hospital, haven an activity load of occupancy (i.e. employed, patients, and visitors). The occupancy has a different time for the starting and ending of work from each part in the hospital. Some locations of the hospital are measured on the days that can be indicated below:

3.1.1. Variation of Air Temperature and RH in OP-Room on 1/7/2019

The room temperature was desired 18-26 ºC during from seasons of the operating room according to standards and guidelines. On this day, room temperature at 8:00 can be decreased down to 24ºC during starting of the operation room, while increased gradually around 8:30 to17:00 during the work of the OP room. The levels of room temperature can be changed from 24 hours period except at ‘’rest’’ time. Because of ‘’at rest’’ time from 17:00 to 8:00, the room temperature and relative humidity are not varied can be stayed a constant at 24ºC and 42% respectively. The OP room had more loads due to maintaining medical staff, therefore the levels of room temperature can be varied during the time working in the OP rooms.

According to ASHRAE, levels were desired the temperature value ranges between 18-26 ºC for the operating room of the hospital. On this day, the room temperature of the operation room is increased gradually at around 16:20 to 26.3 ºC upper than the limits of ASHRAE during working in the OP room of the hospital as seen in Figure (3.1). Also, the levels of room temperature can be varied from 24 hours period except at rest time.

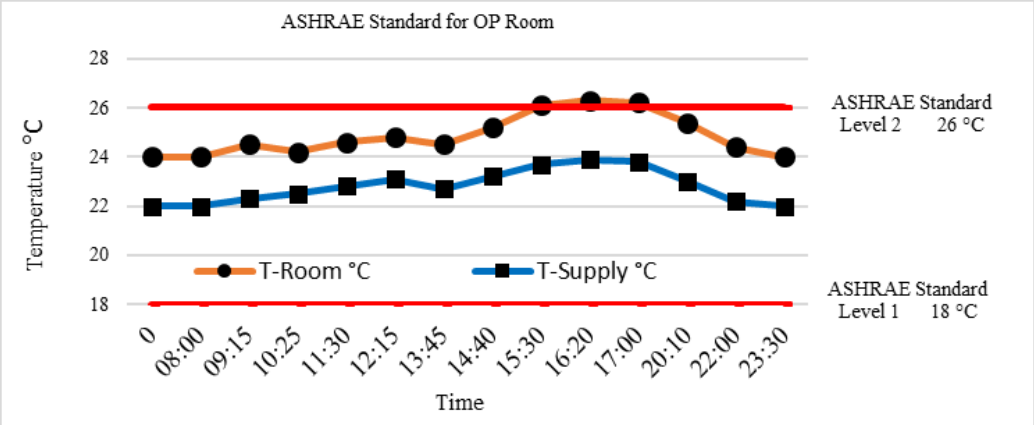

Figure 3.1. Variation of air temperature in the OP room according to ASHRAE standard.

Also, relative humidity in the operating room is kept at around 42% at night and the room temperature is around 24ºC ‘’at rest’’ time on this day of the summer season. The levels of room temperature and relative humidity can stay constant because there was no activity load at rest time in the OP rooms. The levels of relative humidity are increased up to 48%, at the begun of the work and the levels of room temperature are also increased into the OP room. In addition,

the levels of relative humidity may be lowering to nearly 28% due to maintaining the staff of surgery in the OP room.

Relative humidity according to ASHRAE levels were desired value between 30-60% for the operating room of the hospital. On this day, the levels of RH are decreased to nearly 28% at around 15:30 due to more have activity load during work of the OP room as shown in Figure (3.2). The levels of RH can be varied from 24 hours period except at rest time based on the activity load of the operating room.

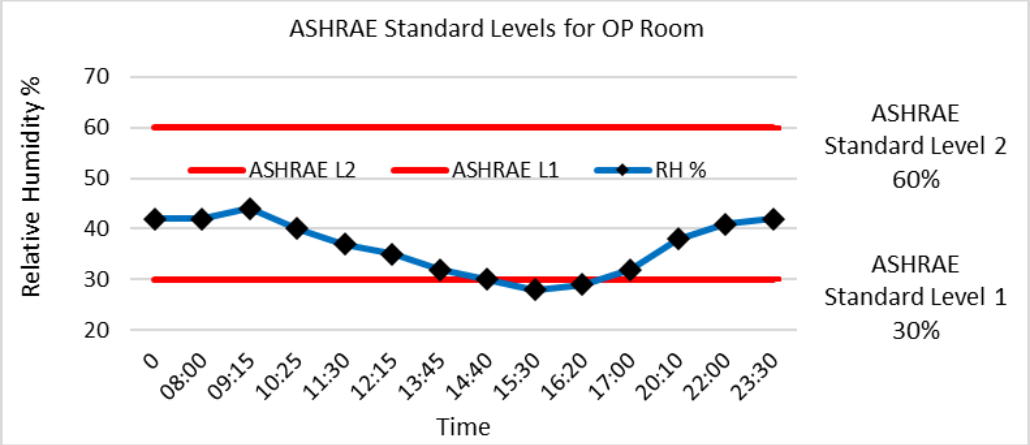

Figure 3.2. Variation of relative humidity in the OP room according to ASHRAE standard.

The levels each of room temperature and relative humidity can be raising and lowering to the limits of ASHRAE standard in the summer season.

3.1.2. Variation of Air Temperature and RH in the (ICU) room on 3/7/2019

In the ICU room, patients stayed that from 24h, since temperature, RH, and air velocity can be varied during 24 hours period in the room. Consequently, room temperature, RH, and air velocity values for the ICU room were 21-26 ºC, 30-60%, and <0.25 m/s, which are accepted that according to standards and guidelines. In the ICU room, the levels of room temperature are kept at around 24ºC, and the relative humidity is around 42% at night ‘’at rest’’ time in the summer season. Also, the levels of room temperature were increased with the activity load began to work, and supply air temperature is commonly varied according to room temperature in the ICU room as seen in Figure (3.3).

According to ASHRAE levels have desired the temperature between 21-26 ºC for the ICU room in the hospital. Also, the levels of room temperature of the ICU room can be increased gradually at around 16:20 to 26.2 from upper the limits of ASHRAE due to having activity load at this time in the ICU room as seen in Figure (3.3). Besides, room temperature can be varied from 24 hours period except at rest time.

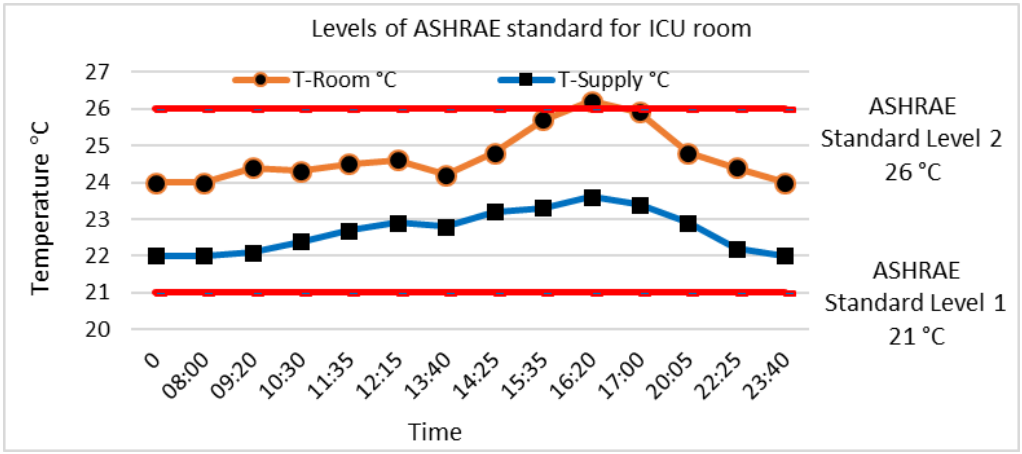

Figure 3.3. Variation of air temperature in the ICU room according to ASHRAE standard.

Relative humidity according to ASHRAE levels were desired value between 30-60% for the ICU room of the hospital. Also, the levels of RH can be decreased to lower than the limits of ASHRAE such as at around 16:20 can be down to 29% due to more have activity load during work of the ICU room as seen in Figure (3.4). Besides, the levels of RH can be raising and lowering depend on activity load.

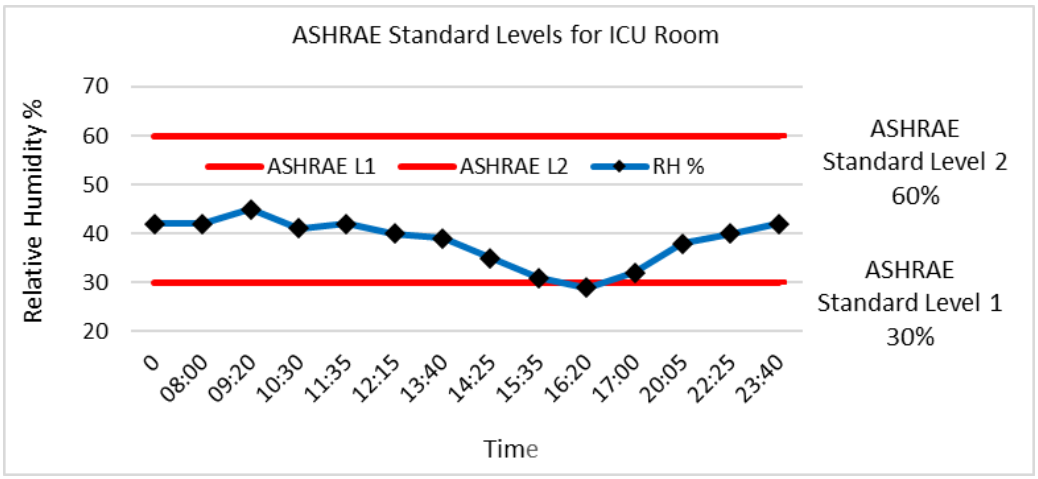

Figure 3.4. Variation of RH according to the ASHRAE standard in the ICU room.

The levels of RH and room temperature can be also raising and lowering to the limits of ASHRAE standard due to more have activity load at this time in ICU room.

3.1.3. Variation of Air Temperature in Different Room Types on 15/7/2019

The room types have a different time for started and ended staff of workers during the experimental period from each part of the hospital. The levels of the parameter of the room types can be changed during 24 hours working period in the hospital. Also, the measurement of parameters of the room types can vary with time off periodically. From Figure (3.5) the levels

of room temperature are higher than the levels of supply temperature on this day of the summer season.

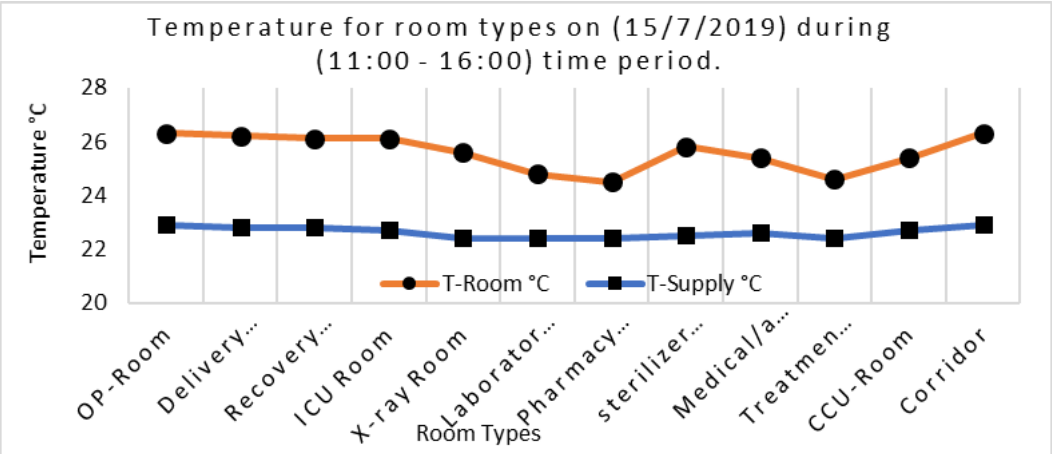

Figure 3.5. Variation of indoor and supply air temperature for Room Types.

The levels of relative humidity and room temperature for the room types of the hospital can be indicated in Figure (3.6). The levels of relative humidity in the OP-room, delivery room, and recovery room are lower than the levels of standards and guidelines, therefore conditions uncomforted in the room types of the hospital.

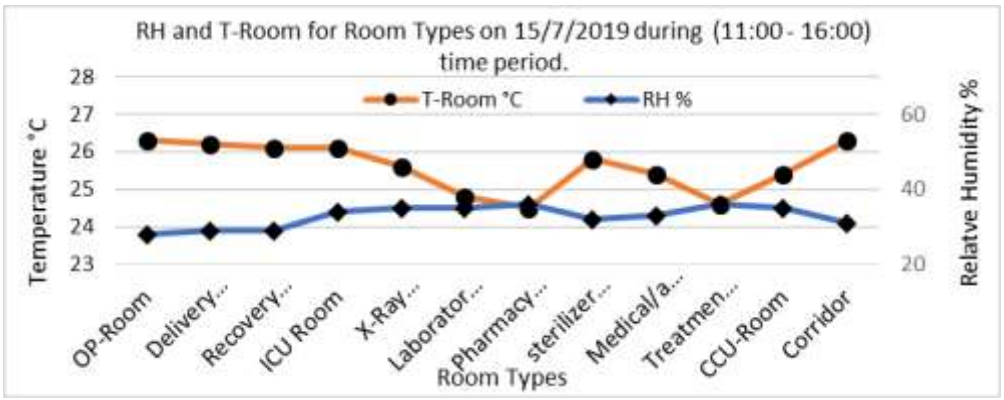

Figure 3.6. Variation of RH and room temperature for Room Types.

The levels each of relative humidity and the room temperature must be inside between the limits of standards to comfort conditions in the room types of the hospital. Sometimes the levels of RH and room temperature may be raising or lowering to the limits of standards, therefore the area has an uncomforted condition of the hospital.

3.1.4. Variation of Air Temperature and RH in Different Room Types on 19/8/2019

During measurement of parameters can be recorded different values for room types in the hospital. On this day, when measured the parameters in the room types can be indicated that the phenomenon on the levels RH and room temperature as seen from the Figure (3.7). According to the results are revealed that the raising values each of them, RH and room temperature in the room types while compared to the other days at last month. The levels of RH and room temperature are varied according to room types depend on climate zone, activity load and time measurement of parameters in the areas of the hospital.

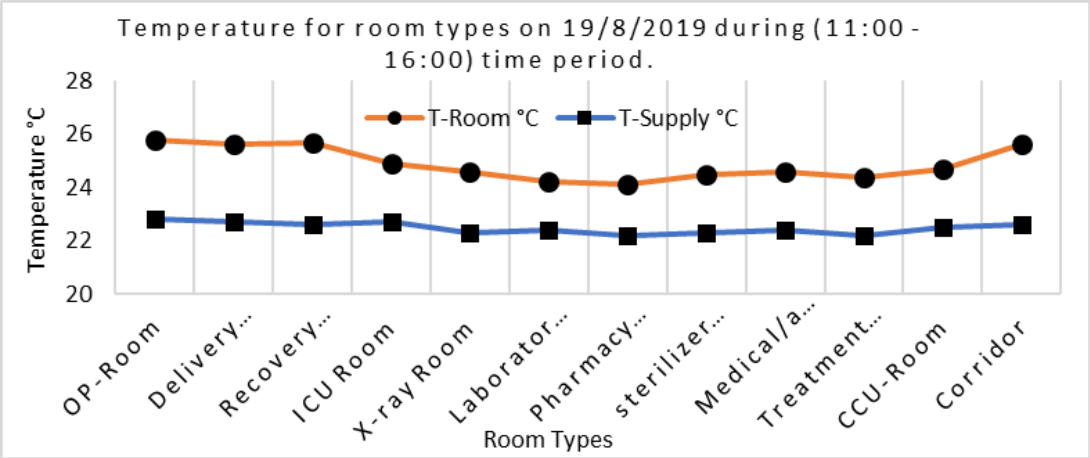

Figure 3.7. Variation of air temperature for different Room Types.

The levels of relative humidity and room temperature are raising in all the room types of the hospital as compared to the other day of last month. The levels of relative humidity and room temperature are varied according to room types of the hospital as seen in Figure (3.8).

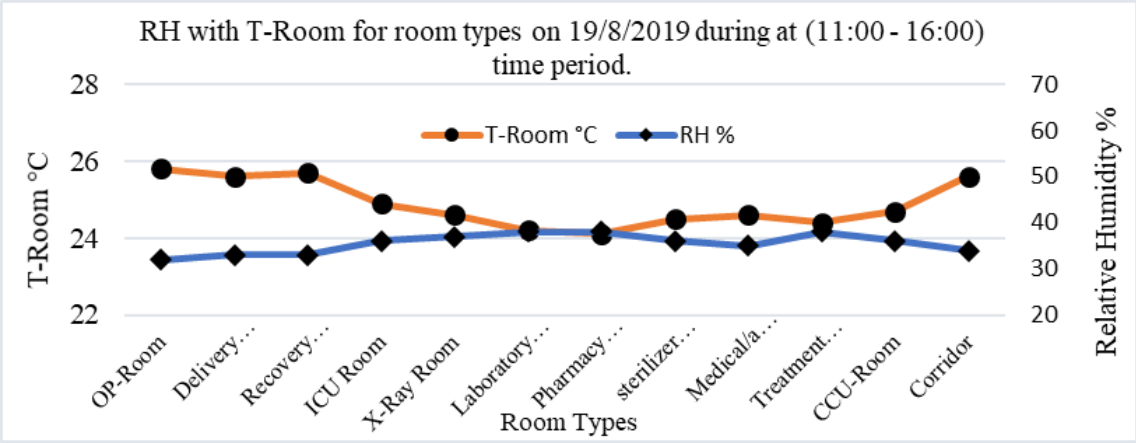

Figure 3.8. Variation of RH and room temperature for Different Room Types

The maximum and minimum levels of the parameter must between to inside the limits of standards and guidelines, for improving conditions in the hospital rooms.

4. CONCLUSION

Thermal condition in hospitals are mentioned to a good design of parameters and good operation of the HVAC system serving to sterile spaces in the hospital according to standards and guidelines. Most standards and guidelines were provided to the satisfactory information about the design of parameters in the hospitals and concrete to distinguish according to their needs of hygiene for the spaces were performed by DIN 1946-4 as Class I and II spaces. The experimental study continued to the measurement of the OP room, ICU room, and room types on daily in the hospital were revealed in the results. When the parameters are calculated to design room temperature can be serving conditions for all types of room in the hospital according to references. The measurement levels of the parameter can be indicated that relative humidity is around 30% and room temperature is around 24ºC, during rest time are stayed a constant in the summer but varies versa in the winter season. The maximum and minimum levels of the parameters must between to inside the limits of standards and guidelines, for improving conditions into room types of the hospital. According to standard levels are mentioned to the requirement of room condition depended on time measured of parameters, and activity load in the hospitals Therefore, lowering or raising of the levels of relative humidity and room temperature are acted to the health of patients and occupants in the hospitals. The parameters calculated to design room temperature can be serving conditions for all types of room in the hospital according to references.

5. RECOMMENDATIONS

- The maximum and minimum levels of the parameter must between to inside the limits of standards and guidelines, for improving conditions into room types of the hospital.
- While above-mentioned standards involve many of the subjects regarding the design, application, planning, production, maintenance, and operation of the hygienic HVAC system in the hospitals.
- Design criteria for the manufacture of products, especially where materials and products exposed to the environment should be a suitable level of cleanliness of the room hospitals.
- The level of air cleanliness for different areas in the hospital should be determined according to the standards and guidelines.
- Appropriate design and controls for the locations and HVAC systems should be in place to achieve containment, cleanliness and suitable levels of safety such as the product, personnel, and environment.
- Design criteria for recommendation value of parameters such as temperature, relative humidity, and air velocity should be maintained under codes according to standards and guidelines in the world.
- Personnel and materials did not move from a higher cleanliness zone to a lower cleanliness zone and back to a higher cleanliness zone. Where this is unavoidable risks should be recognized, and controlled in the hospitals.

- HVAC systems should be ensure attended that to specify room conditions for example through heating, cooling, air filtration, air distribution, airflow rates, and air exchange rates in the room.
- Pressurization in the room of hospital should normally be maintained positive pressure relative to the outside, to prevent the entrance of pollutants.
- For suitability temperature and relative humidity should be controlled, tested and recorded to ensure that the conditions and maintained stability along period time require products a comfortable condition in the rooms.

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