EVALUATION OF INDOOR AIR QUALITY STATUS IN SELECTED COMMERCIAL BUILDINGS IN SAUDI ARABIA: ROLE OF THE HVAC SYSTEMS

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ABSTRACT

Air quality in buildings is increasingly becoming an area of great concern because of its profound impact on occupants comfort, health and productivity. In most buildings, poor Indoor Air Quality (IAQ) can be attributed to the presence of indoor-generated pollutants and the reduced ventilation effectiveness. Recent technological advances and developments in building materials and activities have introduced numerous new pollutants to the indoor space. Additionally, trends to conserve energy and make buildings thermally more comfortable have resulted in airtight buildings, hence allowing little air leakage through their envelopes. This has resulted in the reduction or the elimination of the natural dilution process by outdoor air and increased reliance on the Heating Ventilation and Air Conditioning (HVAC) systems to dilute indoor-generated contaminants. The objective of this paper is to assess the air quality in selected commercial and office buildings in the Eastern Province of Saudi Arabia and to identify measures and considerations during building design and operation for enhancing the effectiveness of HVAC systems for better indoor air quality. Questionnaire surveys and interviews were conducted with the building occupants to assess their level of comfort. Furthermore, walk-through inspections and environmental parameters measurements were carried out in those buildings. Based upon the outcome of the analysis of the study, general guidelines have been formulated for HVAC systems design, operation & maintenance for improved IAQ in hot and humid climates of Saudi Arabia. A checklist was also developed for the evaluation of HVAC systems design, operation & maintenance to ensure proper IAQ requirements.

Keywords: *Indoor Air Quality (IAQ); Heating, Ventilation & Air-Conditioning (HVAC) Systems.*

الملخص

يلقى موضوع جودة الهواء داخل المباني إهتماماً متزايداً نظراً لدورة في التأثير على راحة وصحة وإنتاجية الانسان . ومن المعلوم أن معظم المشاكل المتعلقة بجودة الهواء في المباني تكون إما بسبب وجود ملوثات داخلية نتيجة لتنوع النشاطات والعمليات المنتجة لتلك الملوثات ، او بسبب نقص فعالية عملية التهوية . وقد أدى تطبيق بعض وسائل الحد

من إستهلاك الطاقة الى تفاقم المشكلة حيث زاد الاعتماد على انظمة التهوية الميكانيكية والحد من تسرب هواء النهوية الطبيعي عبر الغلاف الخارجي للمبنى . تهدف هذه الورقة الى دراسة مستوى جودة الهواء الداخلي في بعض المباني التجارية المختارة في المنطقة الشرقية من المملكة العربية السعودية وتحديد العلاقة بين أنظمة التكييف والتهوية وجودة الهواء الداخلي وبالتالي الاستفادة منها في تحديد الاعتبارات التصميمية والتشغيلية لتلك الانظمة لتحقيق الاداء المنشـود. ولتحقيق هذا الهدف فقد تم استقصاء آراء قاطني المباني المختارة ، كما تم إجراء الفحص الميداني لتلك المباني . وخلصت الدراسة الى تحديد الاعتبارات اللازمة في تصميم وتشغيل وصيانة أنظمة التكييف والتهوية والتي تتلائم مع الاجواء المناخية الحارة الرطبة والتي تتميّز بها المنطقة الشرقية بالمملكة العربية السعودية .

1. INTRODUCTION

Generally people spend most of their time inside buildings, where the climate is artificially controlled to achieve the required thermal, acoustical, and visual comfort, in addition to acceptable indoor air quality (IAQ) conditions. IAQ has traditionally been an issue of concern related to odor. But, in the 1990's it has become an area of great concern because of its profound impact on the occupant's health and productivity. More recently, it has been declared by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) as one of the most important research categories with an allocation of 20% of the total research budget in its 1999-2000 research plan [ASHRAE Insights, 1998].

1.1 Indoor Air Quality

Good IAQ is an important component of a pleasant and productive indoor environment. Occupants of buildings with air quality problems suffer from symptoms like eye, nose and throat irritation, dry skin and mucous membranes, fatigue, headache, wheezing, nausea and dizziness resulting in discomfort [Sterling et al., 1993]. Acceptable IAQ is defined in the ASHRAE standard 62-1989 [ASHRAE, 1989] as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80 percent or more) of the people exposed do not express dissatisfaction". This means that health considerations must be made along with the human comfort. Eventually buildings are now classified as healthy or sick. A building is known as "sick" when more than 20% of its occupants exhibit any of the varied symptoms for more than two weeks and such symptoms disappear after leaving the building.

1.2 HVAC Systems

To enhance the comfort and well-being of the occupants, indoor environments have been controlled with extensive and often complicated heating, ventilating and air-conditioning (HVAC) systems. The primary purpose of these systems in a building is to regulate the air dry-bulb temperature, humidity and air quality. These systems employ filtration, water, air

currents, and mechanical and electrical devices which may accumulate organic dusts or microorganisms that become a source of bioaerosols which if inhaled may induce disease on an irritant, toxic or immunologic basis.

It has been established by researchers that HVAC-related inadequacies are the primary cause of most IAQ problems [Sterling et al., 1993]. These problems could arise because of the deficiency in HVAC system design, maintenance, operation, controls, air balancing, and occupancy related issues [Tamblyn, 1992 and EPA, 1998]. These problems could be addressed by adequate design of ventilation and air distribution, filtration, and proper operation and maintenance strategies. In contrast, HVAC systems could create a problem by circulating the contaminated outdoor air or by aiding in the microbial growth, and it could also solve the problem by the provision of adequate fresh air ventilation rate or through proper maintenance of the system.

1.3 Problem Statement

In Saudi Arabia, harsh climatic conditions have made it necessary to use HVAC systems to control the indoor climate of buildings in order to create a comfortable and productive environment. Most part of the year is considerably hot necessitating the constant use of air-conditioners. Almost all buildings are air-conditioned, employing some kind of HVAC system to control temperature, humidity, odor, air quality and ventilation.

Indoor environment in general and IAQ issues in particular, has not been a prime concern for research in Saudi Arabia [Al-Qahthani, 1993]. In order to have an idea about the status of IAQ in Saudi buildings and the impact of HVAC systems, a total of 40 commercial and office buildings were selected for investigation in the Eastern Province of Saudi Arabia. However, the study was conducted in 24 buildings based on the type of HVAC system employed, the ease of accessibility and the size of the building. Buildings with window type air-conditioning systems were not considered for the study. All these buildings are less than twenty years old and are medium to large sized ranging from three to fourteen levels.

2. METHODOLOGY

The evaluative strategies and protocols that have been used by various IAQ investigators show a general consistency and commonality in approach. All these strategies recognize the need to employ a multidisciplinary approach to the evaluation of IAQ problems [Collett et al., 1993]. Hence, a multidisciplinary approach was adopted to achieve the objectives of the study. The approach included (a) the occupants survey, to be acquainted with the occupant's subjective perceptions of comfort in their environment, and (b) the building survey, which includes walkthrough inspection and measurement of environmental parameters, to assess the physical status of building, the HVAC systems, and the objective quality of indoor air.

Top

3. OCCUPANT'S SURVEY

Most of the investigators currently engaged in IAQ evaluation in commercial buildings have developed complementary ways of eliciting feedback from building occupants. Questionnaires administered to occupants range widely in their degree of detail. They focus on symptoms of discomfort or ill health, perceived attributes of the individual's work environment, such as temperature, humidity, odor and other data like duration of stay in the building, type of equipment, etc [Vischer, 1993].

For the purpose of the study presented in this paper, a total of 504 sets of questionnaires were distributed to the occupants of selected commercial and office buildings in the Eastern Province of Saudi Arabia. This questionnaire was administered with the aim of acquiring information on the following aspects:

(a) general information on the occupants: age, occupation, duration of stay in the building, and period of occupation of that particular space

(b) symptoms that the occupants might have observed over a period of time such as headache, irritation, fatigue, skin rash or drowsiness

(c) the respondent's medical history, the behavior of these symptoms, and their perception of work place environment such as temperature, relative humidity, noise level, lighting level, air movement, and odor.

The questionnnaire results were then analyzed to have an overview of the occupant's level of comfort with their surroundings. The symptoms experienced by the surveyed occupants in these buildings are shown in Figure 1.

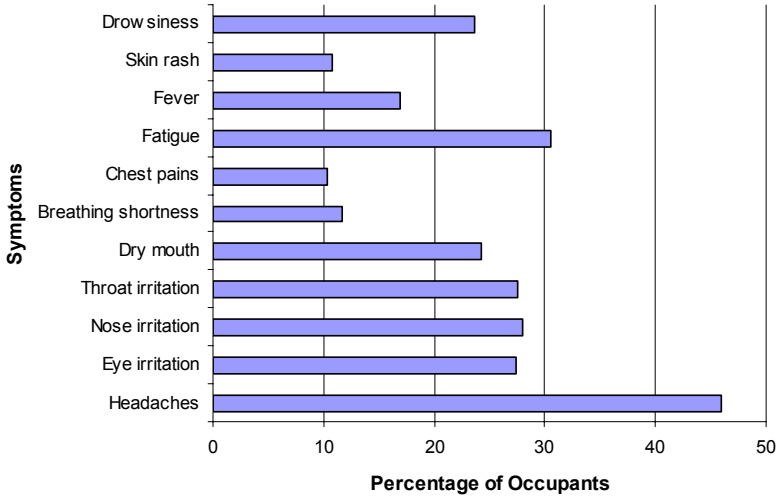

Figure 1: Symptoms experienced by occupants

Headache is observed to be the most common and prominent complaint in all these buildings. This may be due to the presence of airborne pathogen, improper temperature, inadequate light, glare, or noise. The presence of Video Display Units (VDU's) in these areas could also be a probable cause of headache [Raw, 2000]. Fatigue is the next common complaint that has been reported, which could be due to the presence of microbial aerosols, excessive concentration of volatile chemicals, poor labor relations, uncomfortable seating, repetitive motion, or overcrowding.

The Questionnaires inquired the occupants of their levels of comfort or discomfort with the environmental parameters which includes temperature, relative humidity, noise level, lighting level, and air movement. These parameters are the indicators of general comfort conditions in any space and can be indirectly related to symptoms that are associated with poor IAQ. Eighty seven percent of the total surveyed occupants perceive the environment as thermally comfortable if little dissatisfaction is ignored (slightly warm/cool) as shown in Figure 2. Regarding the acoustical performance of buildings, almost 74 percent of surveyed occupants perceive the environment as quite. Almost 89 percent of the occupants are comfortable with the lighting levels in their workspaces. And almost 96 percent of the respondents are comfortable with the air movement.

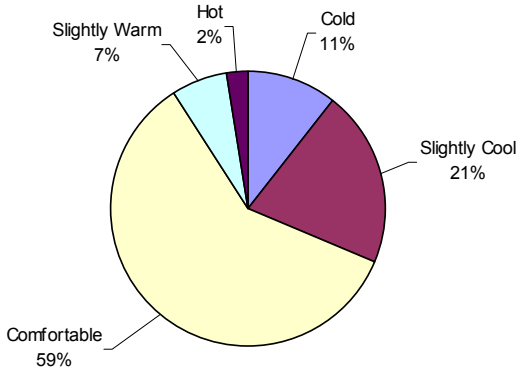

Figure 2: Thermal perception of occupants

Information regarding the HVAC systems maintenance practices and the associated health issues were sought from the occupants of these buildings. Seventy three percent of the respondents reported that the systems are operational throughout the year. This may be due to the weather conditions in the Eastern Province which is usually hot and humid for about 6 to 8 months, and the nature of load in these buildings which is predominantly due to internal load such as people, lights, etc. About 30 percent of the surveyed occupants have complained that HVAC systems provide either too hot or cold environments.

The surveyed occupants were requested to identify the specific complaints pertaining to their air-conditioning systems. Figure 3 illustrates the occupant's complaints related to their HVAC systems in the investigated buildings.

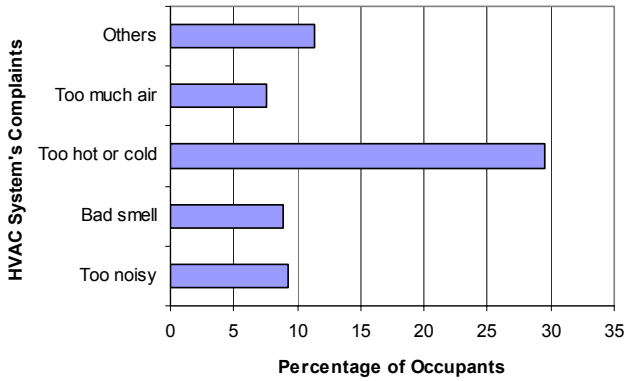

Figure 3: Complaints about HVAC systems

In response to a question regarding the presence of odor in the work environment, about 40 percent of respondents have denied its presence. Twenty eight percent concede that it is present with slight magnitude, whereas another 26 percent perceive it as moderate. Only about 3 percent have complained about strong odor presence. About 40 percent of occupants are tobacco smokers and are not bothered if others too smoke in the enclosures or their work environments. This problem is much severe in the case of commercial buildings that recorded the highest percentage of tobacco smokers inside buildings with about 51 percent of the respondents in these buildings confirmed to be smokers.

Although the occupants of the surveyed buildings did not report any serious dissatisfaction, it is not sufficient evidence to conclude that there are no IAQ problems in these spaces. This could be due to numerous reasons that include (i) the presence of smokers inside the buildings (ii) varied perception of occupants (iii) general ignorance regarding IAQ among occupants, and (iv) some contaminants are not easily sensed by humans. Therefore, it was not appropriate, at this stage, to make a firm conclusion about the status of IAQ in these buildings, instead further investigations are deemed necessary for a better assessment. These investigations include walkthrough inspection and measurement of certain environmental parameters.

4. BUILDING SURVEY

A field survey is carried out that included walkthrough inspection of selected buildings and performance related measurements of environmental parameters. Building information is gathered that is helpful in identifying possible pollutant sources. Information is also obtained regarding the condition of HVAC systems, its operation, and maintenance.

The process involved the following steps:

(i) Interaction with the building owner, owner's representative, manager, operation and maintenance personnel. They were briefed about the purpose of the study and information is gathered regarding the building function, occupant's complaints, equipment's operation & maintenance schedules, breakdowns or other incidents.

(ii) Review of available engineering and architectural drawings. Existing plans and specifications were reviewed wherever possible to be acquainted with the original design regarding the type of HVAC system employed, location and capacity of HVAC equipment, planned use of the space, supply, return, and exhaust air quantities.

(iii) Finally, a walkthrough inspection to examine the existing design configuration and operational condition of the building's HVAC system. Every component of the HVAC system is of interest, either as a source of contamination or as a component that fails to provide the required air-conditioning function.

4.1 Inspection of HVAC Components

The National Institute of Occupational Safety and Health (NIOSH) has reported HVAC systems to be the cause of over 50 percent of all IAQ problems and complaints [Hays et al., 1995]. The importance of HVAC systems could be understood with the fact that these systems are responsible for about 60 percent of the building generated IAQ problems and has the potential to resolve up to 80 percent of the problems [Hansen, 1991].

A visual inspection sheet was developed with the aim of recording the observations about the space characteristics, identification of pollutant sources related to HVAC systems, and the general condition of buildings. The inspection process included the suitability of temperature, humidity, lighting level, noise level, smoke and odor. Cooling coils, ductwork and filters are the potential sources of pollutants in the HVAC systems. Hence, information was obtained regarding their conditions, maintenance schedules, microbial growth, etc. Similarly other general conditions of the space were inspected that include the exhaust systems, mechanical room conditions, contaminant generation areas, location of fresh-air intakes, parking facilities, etc.

Top

The observed temperature, relative humidity, air velocity, lighting levels, and noise levels were within the acceptable range with a little percentage of dissatisfaction as shown in Table 1. These factors are important in the perception of a comfortable environment. However, a serious problem of cigarette smoking has been observed inside most of the inspected buildings.

Table1: Outcome of walkthrough inspection in the investigated buildings

		Percentage of Buildings		Percentage of Buildings		Percentage of Buildings	
SPACE CONDITIONS	Noticeable odor	54	None	46	Moderate	0	Strong
	Temperature	8	Cold	88	Comfortable	4	Warm
	Humidity	0	Dry	92	Comfortable	8	Humid
	Lighting level	4	Low	96	Satisfactory	0	High
	Vibration and noise level	46	Low	54	Satisfactory	0	High
	Dirt	12	Yes	88	No		
	Smoking	83	Yes	17	No		
	Noticeable flow of air	4	Yes	96	No		
	Dampness	0	Yes	100	No		
DUCTWORK	Proper layout for air distribution	100	Yes	0	No		
	Return air plenum	92	Yes	8	No		
	Duct lining	0	Inside	100	Outside		
	Microbial growth in ductworks	0	Yes	100	No		
	Access doors available	100	Yes	0	No		
COOLING COIL	Drain pans trapped properly	100	Yes	0	No		
	Condensation problem	0	Yes	100	No		
	Evidence of water leakage	4	Yes	96	No		
	Microbial growth in condensate pans	0	Yes	100	No		
	Corrosion problem	4	Yes	96	No		
	Inspection access available	100	Yes	0	No		
FILTER	Filter type	100	Media	0	HEPA		
	Condition of filter	38	Excellent	54	Good	8	Bad
	Moisture buildup	0	Yes	100	No		
	Filter location	100	Before	0	After		
	Frequency of cleaning	13	Twice	54	Thrice	17	6-12 month
	Inspection access available	100	Yes	0	No		
INTAKE	Fresh air intake	92	Yes	8	No		
	Bird screen obstructed	0	Yes	96	No		
	Parking facility or road nearby	83	Yes	17	No		
	Exhaust outlet within 25 feet	21	Yes	79	No		
GENERAL	Central exhaust system	38	Yes	62	No		
	Separate smoking areas with exhaust	0	Yes	100	No		
	Doors to building close tightly	96	Yes	4	No		
	Mechanical room conditions	29	Excellent	50	Good	21	BAD
	Controls are operational	100	Yes	0	No		
	Maintenance/inspection schedule	67	Yes	33	No		
	Contaminant generation areas	88	Yes	12	No		

Top

In general, the ducts were found to be in good condition. The duct lining consist of outside fiberglass insulation in most cases. Inside insulation is generally applied to reduce the noise at the mouth of air-handling unit, but it creates IAQ problems by aiding the growth of microbial organisms. The visual inspection did not give any evidence of microbial growth inside the ducts in inspected buildings. Proper layout of air distribution system is important because the airflow patterns that are created from the location of supply and return air grilles in the occupied space affect thermal comfort. The layout of air distribution system was found to be appropriate in most of these spaces.

Cooling coils too were found to be in good condition. There were no major condensation problems noticed in any of the buildings neither any evidence of the microbial growth in condensation pans. Excessive water accumulation at this section usually results in mold growth. The condensate drain pans were found to be properly trapped, and sloped to the drain locations. The equipment inspection access was available and corrosion was rarely seen in these buildings. Corrosion was observed in some of the old equipments in old buildings.

Media type filters are the most commonly used filters in these air-conditioning equipments. Media filters are much finer with high efficient filter paper in pleats within a frame. They work both by straining and impaction. These filters need regular maintenance to prevent the blockage [Stein and Reynolds, 1992]. Most of the inspected filters were found to be considerably clean. Fresh air intakes are available in most of the inspected buildings which were usually provided with a mesh or a bird screen to prevent large debris from entering into ducts and creating problems for air quality.

It was noticed that the maintenance and inspection schedule is available in 67 percent of the inspected buildings. Others do not have a fixed schedule, they rather rely on complaints from occupants to correct the problem. There were no separate areas for tobacco smoking with local exhaust in any of the investigated buildings. Rather it was observed that the smokers are smoking indiscriminately in all areas.

4.2 Measurement of Temperature, Humidity, and CO_2 Levels

Instrument measurements were carried out to record temperature, relative humidity, and CO_2 concentrations. Most of the previous investigations for IAQ have aslo involved the measurements of these parameters [Collett et al., 1993, Gan et al., 1994, Grot et al., 1991].These measurements were undertaken in peak occupancy conditions. It was encouraging to find that the recorded parameters in most of these buildings were within the ASHRAE comfort zone as shown in Figure 4.

The temperature recorded in these buildings ranged between 23^{o}C to 26^{o}C. The relative humidity was recorded in the range of 35 to 60%. CO_2 concentrations were below the permissible limit of 1000 ppm in most of these spaces. Percentage of outdoor fresh air entering the building is also estimated. Since the measurements were carried out for an hour during high occupancy period, the results provide an indication of the overall conditions of spaces in the investigated buildings.

Top

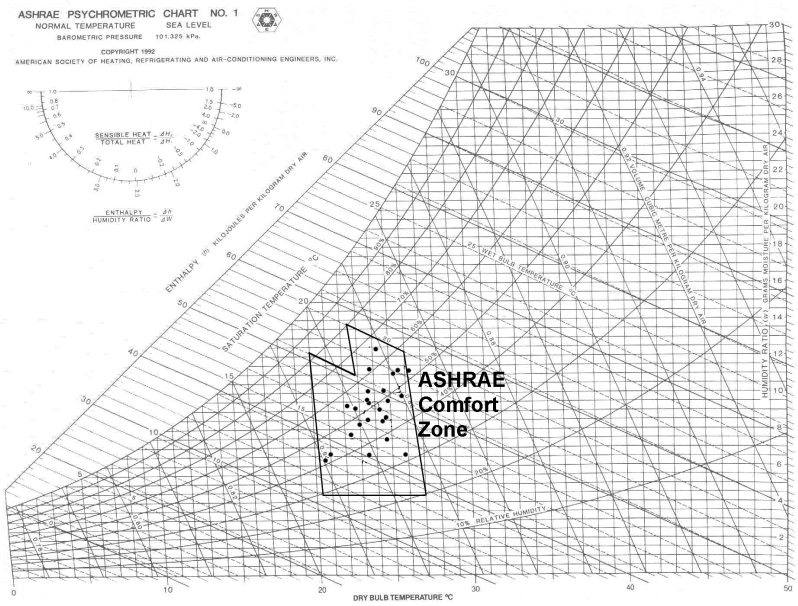

Figure 4: Recorded temperature and humidity on psychrometric chart

5. CONCLUSION

The outcome of the surveys and measurements suggest that a majority of the buildings are thermally comfortable. A majority of surveyed occupants have shown satisfaction with the levels of temperature, relative humidity and air velocity. The same was observed during the walk-through inspection of buildings. The quantitative measurements of temperature and relative humidity confirmed the readings to be within the acceptable limits. The recorded carbon dioxide levels in a majority of buildings were also found to be within the acceptable limits. This could be deduced from the general satisfaction of the occupants with their surroundings.

Based on the results of building occupant's survey and building survey it is concluded that there is no significant air quality problems in most of the investigated commercial and office buildings. The HVAC components that include ductwork, cooling coils, filters, fresh air intakes, and mechanical room conditions were generally in good condition. Cigarette smoking has been observed inside most of the investigated buildings. Hence, there were no serious IAQ problems found to be associated with the HVAC systems in the investigated commercial and office buildings in the Eastern Province of Saudi Arabia.

The conclusions of this study could not be generalized for all commercial buildings in Saudi Arabia. However, it presents a trend of IAQ in these type of buildings. In order to alleviate the problems related to air quality, two separate easy-to-use checklists have been formulated that can be used by HVAC designers, and HVAC operation & maintenance personnel for

improved IAQ in commercial and office buildings of Saudi Arabia (see Appendix). These checklists comprise the various components of HVAC system. The correct answer boxes are shaded for the convenience of users.

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Top

APPENDIX

1 – HVAC Design Checklist for IAQ

Outside Air Intake		Yes	No	Comments
1	Unobstructed location of outside air intake louvers?			
2	Outdoor air quality follows standard criteria?			
3	Ventilation rate according to ASHRAE standard 62-1999?			
4	Exhaust outlet within 7.6 m (25 feet) of the fresh air intake louvers?			
5	Are outside air intake provisions away from road/parking areas/garbage dumps?			
6	Bird screen of 1/2" minimum spacing at the air intake ductworks?			
7	Accessibility for cleaning?			

Mixing Plenums		Yes	No	Comments
1	Any fibrous or moisture absorbing material in direct contact with air?			
2	Proper floor drain inclination?			
3	Accessibility for cleaning?			
4	Negative pressure in mixing plenums?			

Filtration		Yes	No	Comments
1	Are filters designed with sufficient efficiency to ensure adequate arrestance?			
2	Are filters properly located along the air stream depending on contaminant source?			
3	Is there a complete coverage of air without any bypassing?			
4	Moisture absorbing material used for filters?			
5	Air velocity at filter section is 1.5 m/s (300 fpm)?			
6	Static pressure drop at filter section is 0.7 to 0.8 inch of w.g.?			
7	Easy access to filters for maintenance and replacement?			

Cooling Coils / Condensate Pans		Yes	No	Comments
1	Is it ensured that there is no water carryover from cooling coils into the ductwork?			
2	Are the supply air ducts internally insulated?			
3	Air velocity at the cooling coil section is 1.5-4 m/s (300-800 fpm)?			
4	Is the condensate pan drain properly sloped and connected to the sewer system?			
5	Accessibility for inspection and maintenance?			

(continued…)

Supply Air Fans		Yes	No	Comments
1	Are the fans properly sized to overcome the resistance of ductwork, supply outlets, return intakes, cooling coils, and filters?			
2	Are the fans draw-through type?			
3	Accessibility for inspection and maintenance?			

Supply Ductworks and Accessories		Yes	No	Comments
1	Are the duct velocities as follows: 5-6.6 m/s (1000-1300 fpm) for main ducts, 3-4.6 m/s (600-900 fpm) for branch ducts, and 3-3.6 m/s (600-700 fpm) for branch risers?			
2	Is the static pressure loss for various ductwork components are as follows: 125 Pa (0.50 inch of w.g.) for supply plenum, 12.5 Pa (0.05 inch of w.g.) for supply grille and return plenum, and 100 Pa (0.40 inch of w.g.) for ducted return?			
3	Is there a proper layout of ductwork for proper air quality delivery, uniform air distribution, and minimum pressure drop?			
4	Is there a provision to control volume dampers for air-balancing?			
5	Are the ducts externally insulated?			
6	Accessibility for inspection and maintenance?			

HVAC Controls		Yes	No	Comments
1	Is the design temperature within the range of (a) 21 to 23 deg.C (70 to 74 deg.F) for winter (b) 23 to 26 deg.C (74 to 78 deg.F) for summer?			
2	Is the design relative humidity within the range of (a) 20-30% for winter (b) 50-60% for summer?			
3	Is the air movement within the range of 0.127 to 0.229 m/s (25 to 45 fpm)?			
4	Is the air circulation within the range of 4-10 air changes per hour?			
5	Are the thermostats properly located?			
6	Does the noise levels exceed 40-45 NC (maximum)?			

(continued…)

Exhaust Fans		Yes	No	Comments
1	Are the exhaust systems provided to all toilets, kitchens and other contaminant generating areas?			
2	Is there sufficient makeup air provided to compensate for the exhaust air?			
3	Are the exhaust areas slightly negatively pressurized to rest of the building?			
4	Are the garage/parking areas within the building designed at slightly negative pressure relative to the building?			
5	Are the smoking lounges provided with 100 percent exhaust?			
6	Accessibility for inspection and maintenance?			

Mechanical Room		Yes	No	Comments
1	Are the mechanical rooms properly located in the building?			
2	Is there an unobstructed access to all components for inspection and maintenance?			

2 - HVAC Operation and Maintenance Checklist for IAQ

Outside Air Intake		Yes	No	Comments
1	Are the outside air louvers and bird screens unobstructed?			
2	Are the outside air dampers operational and balanced?			
3	Does the outside air damper seals completely when closed?			
4	Is there standing water or bird droppings within the vicinity of outside air intake louvers?			
5	Are there any contaminants or odors that enter through outside air intake?			
6	Are the air louvers and bird screens regularly cleaned?			

Mixing Plenums		Yes	No	Comments
1	Are the outside air dampers, return air dampers, and exhaust air dampers balanced to ensure proper proportional mixing?			
2	Are all damper motors operational?			
3	Is the floor drain trapped properly without any standing water?			
4	Is the mixing plenum free from corrosion?			
5	Is the mixing plenum maintained in clean condition?			

(continued…)

Filtration		Yes	No	Comments
1	Is pressure drop across the filter as per manufacturer's recommendation?			
2	Are the filters accessible to inspect and clean?			
3	Is there a regular inspection for any signs of blockage / microbial growth?			
4	Are the filters cleaned and replaced on a regular basis?			
5	Are the filters inspected for their type and size to ensure complete coverage without bypassing?			

Cooling Coils / Condensate Pans		Yes	No	Comments
1	Are there any signs of condensation problems?			
2	Are the cooling coils / condensate pans maintained, and accessible to inspect and clean?			
3	Is there any water accumulation or microbial growth in condensate pans?			
4	Are the cooling coils free from scaling / corrosion?			

Supply Air Fans		Yes	No	Comments
1	Are the supply air fans accessible to inspect and clean?			
2	Are the fan blades cleaned for dust / dirt accumulation?			
3	Are the fan belts provided with proper tension?			
4	Are the vibrations maintained at minimum level?			
5	Are the fans inspected for any signs of corrosion and their proper painting is ensured?			

Supply Ductworks and Accessories		Yes	No	Comments
1	Are the ductworks cleaned at least once in two years?			
2	Are there for any leakages in the ductworks?			
3	Are the volume control dampers operational and balanced?			
4	Are all the access doors in ducts closed to prevent any undesired entry?			
5	Are the ductworks balanced within 3-5 years or after renovations?			
6	Is there a uniform air-distribution to all the space?			
7	Are there any signs of corrosion in grilles / diffusers?			
8	Are the grilles / diffusers cleaned on a regular basis?			

(continued…)

HVAC Controls		Yes	No	Comments
1	Is there a proper temperature and humidity setting for winter and summer?			
2	Are the actual space temperature and humidity recorded and then compared with the standards?			
3	Are the space occupants satisfied with indoor environment?			
4	Are the temperature and humidity settings adjusted if warranted?			
5	Are all the HVAC controls in proper working condition?			

Pollutant Pathways		Yes	No	Comments
1	Do the stairwells close and latch without any opening for uncontrolled airflow?			
2	Is the return air path unobstructed?			
3	Are the ducted returns balanced every 3-5 years or after renovation?			

Exhaust Fans		Yes	No	Comments
1	Are all exhaust fans are operational?			
2	Is there an unobstructed sufficient makeup air to compensate for exhaust air?			
3	Do the doors to building close tightly to prevent any infiltration of contaminated air?			
4	Do the toilets, kitchens and parking areas have negative pressure relative to the building?			
5	Is there any provision to eliminate smoking or isolate smoke source in terms of time and space by assigning separate smoking area?			
6	Are the smoking lounges provided with 100 percent exhaust?			

Mechanical Room		Yes	No	Comments
1	Is the equipment in overall good condition?			
2	Are all the controls operational and calibrated?			
3	Are the control drawings posted?			
4	Is the sump of cooling tower clean and there are no signs of slime / algae / bacterial growth?			
5	Are the biocide treatment and dirt separator working for cooling tower?			
6	Are there any leaks of refrigerant in chillers?			
7	Is there any material storage in the mechanical room that may obstruct easy access to the equipment?			

Top