

Effectiveness Of UVC Lights Irradiation To Improve Energy Saving

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Abstract: HVAC (Heating, Ventilation and Air conditioning) is the largest consumer of energy in commercial and industrial buildings. HVAC systems account for an approximated 50% of energy use in buildings. The sources of contamination and odour comes from the growth of bacteria, mold and fungus that accumulate and develop on wet surfaces of HVAC coils and drain pans ,causing respiratory infection, cough, tight chest and wheezing. Besides the effects on human health, Fungal contamination that adheres to the fins of cooling coil of air handling unit (AHU) cause a significant increase in pressure drop across the coil and decrease in heat exchange efficiency , which Leads to loss of cooling capacity and additional energy use. To prevent the fungal and microorganism growth on the cooling coil and drain pan of HVAC systems, many studies conducted but not all these solutions were sufficient to remove microbial organism from the HVAC 100 %. The UV-C light options, through a process known as UVGI (Ultraviolet germicidal irradiation) is a technology showed a significant impact to produce clean air and improve indoor air quality [16]. UVGI lights produce short wavelength light kills microorganisms, including viruses, bacteria, mold and many other fungi by disrupting their DNA. The effectiveness of UVGI installed inside HVAC systems depends on many factors and the application Methods in HVAC systems. A few studies showed whether the use of (UVGI) results in energy saving. The objective of this study is to find the effect of fungal growth on the cooling coil surface by using field measurements at actual operating conditions of heat transfer and air flow for a non-irradiated coil in comparison to irradiated coil .Hence evaluate if there would be an enthalpy change at the coil and document the effectiveness of UVGI coil cleaning on restoring cooling capacity and save energy.

Index Terms: UVGC, HVAC, Sample Collection, Energy Saving, Characterization, DX-System, AHU Units

1. INTRODUCTION

HEating, Ventilation and Air-conditioning (HVAC) system reported as a source for foul smell. Growth of mold and negative bacteria on the evaporator coil, drain pan and air duct causes sick building syndrome (SBS) and lower (HVAC) system capacity performance which translates into increased energy use in buildings. In the past decade, control of mold growth and fungi in indoor environments has focused on coil cleaning, ventilation and purification cleaning. Chemicals used to limit and control microorganism growth and to clean the coils. Ventilation is ineffective, however, when the HVAC is contaminated or outdoor air introduces outdoor bio aerosols. Certain ways are presented of how to disinfect indoor environments and remove contamination from HVAC systems. One technology that is currently being used is ultraviolet germicidal irradiation (UVGI or UV-C). This study was conducted in through different building of Public Authority for Applied Education and training in the state of Kuwait. The study investigates the improvement of heat- exchange efficiency rates which reduce energy consumption and maintenance costs. The building was constructed in 1992. Some buildings are equipped with DX-Package A/C units and other buildings are equipped with Air handling units (AHU) which connected to a chilled water system. Samples were obtained from (AHU) and ducts and sent to microbiology laboratories for study. Beginning May 2015 UV Lamps Installed downstream of cooling coils of the AHU's. Dust of insulation samples was collected to develop the sampling protocol and study the effect of fouling at the cooling coil on indoor air quality (IAQ) and HVAC system operational costs.

2. BUILDINGS AND HVAC SYSTEMS

The HVAC system is designed to control and regulate the indoor environment by maintaining the building at the desired temperature, relative humidity and excellent indoor air quality (IAQ). When operating as new, it complies with design and standards. But as HVAC system ages, it would result in (IAQ) complaints and system capacity to remove

heat from air-conditioned space, becomes inefficient. The inefficiency mainly results from the accumulation of contamination on the fins of the HVAC system cooling coil areas. Many research studies conducted by carrier [6], American society [1] showed that a fouled coil as a pollutant source for foul smell and significantly contributes to rates of respiratory disease, asthma symptoms and sick building symptoms. Also [13, 14] reported the air conditioning performance was reduced by (35 – 45 %) in the contaminated cooling coil. Although the addition of UVC light to an HVAC system has major effects on fungi [15], only a few investigations have focused on degraded air-conditioning performance, increase in energy, drop in efficiency and loss in cooling capacity.

3. EXPERIMENTAL SECTION

3.1 SAMPLE COLLECTION, PREPARATION AND FINDINGS

An experimental study was conducted on two DX-package units at main headquarter (Constructed 1992) and two AHU units at the Industrial training institute at Shuwaik (Constructed 2000) of the Public Authority of Applied Education and Training. The aim of the study to determine the effectiveness of UVC radiation for reducing fungal contamination within HVAC units and lower energy costs by improving heat transfer and increasing cooling capacity. Preliminary, early April samples were collected for investigation, no UV lamps had been fixed in these units. These samples were sent to microbiology laboratories in the science laboratory to check out if there is any bacteria or mold accumulation on the cooling coil and duct.



Figure 1: Take sample from duct

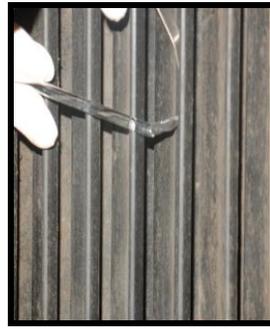


Figure 2: Take dust sample from AHU

Agar (PDA) and Mac Conkey, spread over the entire surface with the aid of the spreader.

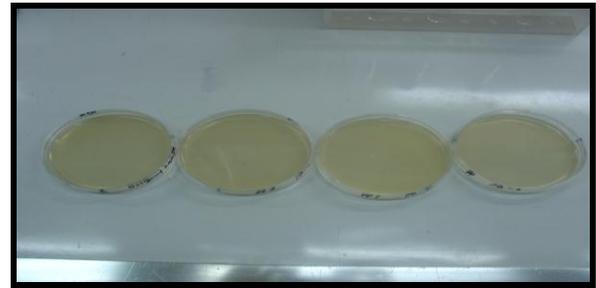


Figure 5: The sample in NA and PDA media

At the end of sample collection the following test procedure was followed:

- 3.1.1. Examination of microorganisms is dated from different environmental sources.
- 3.1.2. Examine the microorganisms is dated from different locations on different agar culture media, such as Nutrient Agar (NA), Potato dextrose agar (PDA), and mac Conkey.
- 3.1.3. Qualitative of the sample from different location



Figure 3: Four dust sample from different place

- 3.1.4. Weight original sample and add the sample into 9ml of sterile water.

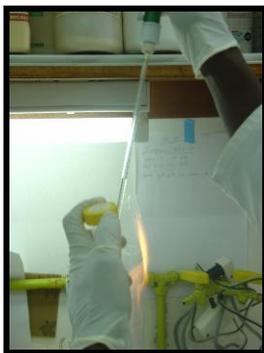


Figure 4: Add sample into 9ml sterile water

- 3.1.5. Aseptically, transfer (1ml) of this sample into another 9ml of sterile water in a tube labelled dilution 10-1.
- 3.1.6. Shake the tube to ensure thorough mixing and transfer (1ml) to another (9ml) of sterile water in a tube marked dilution 10-2.
- 3.1.7. Add (0.1ml) of the original sample to the surface of sterile 10-1. Nutrient Agar (NA), Potato dextrose

- 3.1.8. Similarly, add (0.1 ml) of dilutions 10-1 on plates of NA, DNA and Mac Conkey and spread.
- 3.1.9. Use the same method for all dilutions (10-2 ... 10-6).
- 3.1.10. Incubate the plates at room temperature till observe appreciable growth.



Figure 6-A: The bacteria and mold growth After 24 hours



Figure 6-B: The bacteria and mold growth After 48 hours

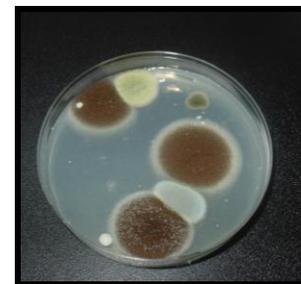


Figure 6-C: The bacteria and mold growth After 72 hours

3.1.11. Examination of microorganisms

- Count # of only bacterial colonies on the NA plates using Colony counter.
- Count # of only fungal colonies on the PDA plates.
- Cultural characteristic of microscopic examination of the most common bacterium in the NA plate using the simple –staining method.

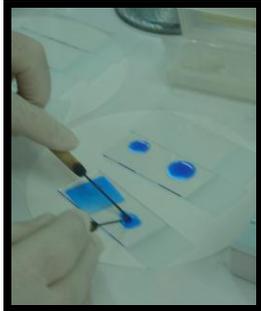


Figure 7-A: simple –staining method for bacterium

Figure 7-B: LPB-stained wet mount method for fungus

Table 1 : Types of Fungus and bacteria's found in tested samples

No	Sample #	Diluted percentage	PDA media	NA media
1	1	0	-Aspergillus's niger -Aspergillus's flavours -Alternaria	-G-ve rod shape.
2	1	10 ⁻²	-Cladosporium	-G-ve rod shape (pseudomonas avgenosa). -G+ve rod shape.
3	2	0	-Aspergillus's	
4	3	0	-Alternaria	
5	4	0		-G+ve rod shape (Bacillus sp).
6	4	10 ⁻²		- Staphylococcus. - G+ve rod shape (Bacillus sp).

Note: We note that there was not any type of G-ve bacteria growth in Mac Conkey media, therefore we neglect it.

- For the most common fungus in the PDA plates using LPB-stained wet mount method.



Figure 8: Using electronic microscopic attached with camera to get pictures for fungus and bacteria's

3.1.12. Colony counters

- If the plates contain few # of colonies, use manual counting.
- If the plates contain moderate # of colonies, use colony counting.
- If the plates contain too many # of colonies, consider as over growth (O.G).

3.2 ANALYSIS AND CHARACTERIZATION

The following table show the different type of fungus (mold) and bacteria's that found in PDA and NA media respectively.

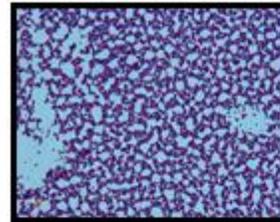


Figure 9: Staphylococcus

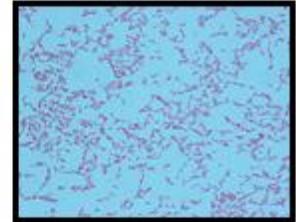


Figure 10: G-ve rod shape (Pseudomonas avgenosa)



Figure 11: Cladosporium

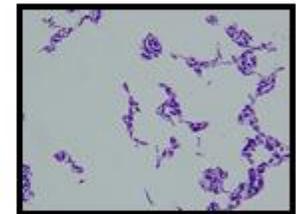


Figure 12: G+ve rod shape (Bacillus sp)



Figure 13: alternaria

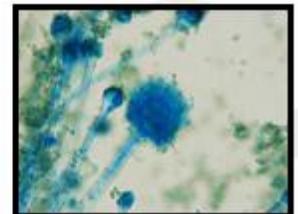


Figure 14: Aspergillus's sp

Table 2: Summery of the results of DX – System Data

S	Measured Parameters	Before treatment with UVC	After Treatment with UVC
1	Air quantity flow (CFM)	7000	7500
2	Entering air temperature – dry Bulb °F	78	80
3	Entering air temperature – wet Bulb °F	67	67
4	leaving air temperature – dry Bulb °F	61.7	59.3
5	leaving air temperature – wet Bulb °F	57.9	55.9
6	Total cooling capacity BTU / h	205799	265315
7	Sensible heat BTU / h	123653	168541
8	Latent heat BTU / h	82146	96774
9	Net cooling capacity gain BTU / h		59516
10	Energy efficiency improvement		28.9 %
11	Energy saving		22.4 %

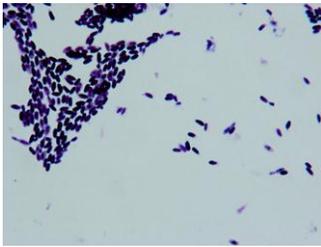


Figure 15: G+ ve rode shape

3.3 ULTRAVIOLET GERMICIDAL IRRADIATION

Laboratory examination for each type of sample collected the dominant fungi and different biological contaminant found on cooling coil and drain pan of the A/C units. At first prior to fixing UV Lights at selected units, measured air flow, entering dry bulb (EDB), leaving dry bulb (LDB) , entering wet bulb (EWB) and leaving wet bulb (LWB) temperatures and coil pressure drop was registered for the first week of May to establish a baseline dataset. The UVC Light installed at (60 cm) downstream from cooling coil and above the drain pan. The irradiance at the coil surface was (166 μW / CM2) for DX-package units, and (195μ W / CM2) for AHU units. The lamps operated 24 hours a day for 100 days starting on 15 Th of May. Data gathered from both systems every 20 days. It was noticed during data gathering an increase in temperature differential across cooling coil as time goes by and this yielded to increase in the air flow and reduce the system energy use. Sections (3.4 , 3.5) shows the gathered and calculated data.

3.4 DX-PACKAGE SYSTEM DATA AND RESULTS

This test is one of very few DX-Systems equipped with UVC Lights that also involved in fungi accumulated on cooling coil in actual installations. For performance evaluation on DX-package air conditioning system, set of field measurements at actual operating conditions (table 2) registered. Populating known total heat equations with collected readings, the pressure drop across the cooling coil decreased, system air flow increased from 7000 CFM to 7500 CFM (an increase of 6.66%). Readings used along with a psychrometric chart to determine the enthalpy (heat content of air at the coil inlet and outlet) and both sensible and latent load calculated. Unit went from 205799 BTU / hr to 265315 BTU / hr. total heat removed (28.9 %). The energy saving (22.4 %) is also a result of improved heat transfer efficiency level of the cooling coil.

3.5 AHU UNITS DATA AND RESULTS

Measurement before and after treatment with UVC Lights of two Air handlers (AHU) were documented. Data collected during the test period, the study yielded to the results shown in table (3).

Table 3: Summery of AHU readings and results

Measured parameters	Air QTY CFM	Cooling Coil (Air Side)						Chilled water			
		TCC BTU/hr	Sensible capacity BTU /hr	ENT Air Temp		LVG Air Temp		ENT Temp °F	LVG Temp °F	Temp Rise	Internal static pressure I.WG
				D.B °F	W.B °F	D.B °F	W.B °F				
Before treatment	7000	234059	187431	82.9	68.2	58.2	58	44	50	6	1.1
After treatment with UVC	8250	315000	227237	80.6	67.1	55.2	55	47	56	9	0.8

4. CONCLUSION

The addition of UV-C Lights by itself doesn't save energy, it restores the coil's performance. The use of germicidal UV irradiation in A/C systems significantly prevent concentration of microbial build up on cooling coils, air filter, duct surfaces and drain pan in commercial air handlers. This study yielded that the use of ultraviolet germicidal irradiation in air conditioning applications improves indoor air quality, reduce maintenance costs, increase the heat transfer of cooling coil, reduce pressure drop across evaporator and therefore resulting in energy savings. The energy saving resulted of improved airflow and reduction in fan energy. The benefits of UV-C solves indoor air quality issues and shown significant energy improvement and prove to be an excellent tool for energy saving aim for many buildings using HVAC systems. A fouled cooling coil is not normally obvious by appearance alone. If Air Handler (AHU) is unable to meet the load, a fouled coil can be one of the main problems. This can be determined by measuring air flow and comparing with manufacturer technical catalogue. A more correct procedure to make the determination would involve collecting air and water temperature differential across the cooling coil. Referring to table (3), after introducing germicidal UV irradiation technology the concentrations of fungi were significantly lower. Internal static pressure decreased by 27% resulted in an air flow rate increase from 7000 CFM to 8250 CFM and helps save fan energy. AHU chilled water (ΔT) increased from (6 °F) to (9 °F) which presented a significant increase of 6.75 tons of cooling added to the building. A clean coil sees a maximum heat transfer across cooling coil, improved air flow and maximize energy saving.

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