SUMMARY REPORT

Background levels of viable bacteria and fungi in the indoor air and on surfaces in Ingham Regional Medical Center *"before and after"* the UVGI-HVAC installation

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INTRODUCTION

The objective of this project was to assess microbial concentrations in air and on fomites in Ingham Hospitals before and after the installation of a UVGI-HVAC system. Using bacteria and fungi concentrations as a standard of effectiveness of the UVGI-HVAC system, indoor air samples were collected before and after installation and microbial levels were compared. Using the impingement method as described by Jensen and Schafer (1998) viable microorganisms (*E. coli*, total bacteria, Staphylococci, MRSA, and fungi) were sampled in the air. This study also investigated indoor surface contamination because fomites have been shown to act as reservoirs for spreading diseases (Morens, D. M., and V. M. Rash. 1995; Bures et al. 2000; Barker, J. 2001; Barker et al. 2004; Kramer et al. 2006; Boone and Gerba 2005). Preliminary samples were collected in the summer of 2007 and post UVGI installation samples were collected in the fall of 2008. Both pre/post installation samples were collected in the emergency department waiting room and cardiac intensive care unit of the Greenlawn Campus and in the UCC waiting room and patient room in 1E at the Pennsylvania Campus.

MATERIALS AND METHODS

Study sites

- Ingham Regional Medical Center, **Greenlawn Campus**, 401 W. Greenlawn, Lansing, MI, 48910
    - Emergency department waiting room: **(GW)**
    - Cardiac intensive care unit: **(GC)**
- Ingham Regional Orthopedic Hospital, **Pennsylvania Campus**, 2727 S. Pennsylvania Ave, Lansing, MI 48910
    - UCC waiting room **(PW)**
    - Empty patient room 1E: **(PE)**

Sampling

Bioaerosols

Bioaerosols were drawn into all glass impingers (AGI-30, Cat # 100550-372, VWR, West Chester, PA), which contained 20 mL of 0.3mM of phosphate buffer dilution water (PBW), using portable pumps (Leland Legacy, Cat # 100-3002, SKC, Eight Four, PA) at flow rate of 12.5 L/min (Jensen and Shafer 1998). Approximately 1500 L (4 impinges x 30 min vacuuming with the flow rate of 12.5 L/min) of air was collected from each room (Figure 1). The sample solutions in the impingers were placed into new sterilized vials after collection. The impingers were rinsed using 5 mL of PBW and the rinsates were added to the sample vial. The sample tubes were stored at 4°C and processed within 24 hours after the sample collection.

Fomites

Fomites were wiped using Fellowes Surface Cleaning Wipes (STRATUS Inc., Amarillo, TX), which were premoisten antistatic wipes. Prior to the sampling, a sheet of original wipe cloth was cut to one forth size (48 cm^2) using sterilized scissors, placed into sterile whirl pack bags, and placed under a UV lamp for disinfection. In each room, 10 selected surfaces (five commonly touched (e.g. chairs, tables, door knobs) and five untouched (e.g. window or picture frames, top of clock, fire alarms)) were wiped back and forth over the entire surface area of approximately

10 cm^2 using several vertical strokes, then folded with the fresh side of the wipe exposed, and several horizontal strokes were made over the same area with the other side of the wipe (Figure 2). After the sampling, the wipes were placed in 10 mL of phosphate buffer saline plus 0.01% Tween-80 (PBST) in 50-mL tubes. Types of fomites and sampling areas were recorded after the sampling.

Figure 1: Bioaerosol sampling

Figure 2: Fomite sampling

Microbial assays

Collected bioaerosol and wipe samples were assayed with culture methods to measure viable microorganisms. Selective agars, i.e. Tryptic(ase) Soy Agar (TSA) for mesophilic bacteria and thermophilic actinomycetes, Mannitol Salt Agar (MSA) for *Staphylococcus*, CHROMagar for methicillin resistant *Staphylococcus aureus* (MRSA) and Malt Extract Agar (MEA) for total fungi were used in this study.

Arithmetic averages were developed for each assay and location before and after installation of the UV system. Non-detects were used as limits of detection.

SUMMARY RESULTS AND DISCUSSION

Bioaerosols

Pre installation tests detected viable bacteria and fungi from indoor air samples collected at the study sites. The concentration of mesophilic bacteria (MB) and thermophilic actinomycetes (TA) ranged from 12 to 56 CFU/m^3. Staphylococcus concentrations ranged from below the detection limit (3 CFU/m^3) to 9 CFU/m^3 for *S. aureus* and 13 CFU/m^3 for the total Staphylococci (e.g. *S. epidermis*). Total fungi concentrations ranged from below detection limit to 6 FU/m^3.

Post installation testing detected only slightly lower viable bacteria and fungi from indoor air samples collected at the same study sites. MB and TA were present in concentrations ranging from below detection limit (<0.33) to 62 CFU/m^3. Staphylococcus concentrations ranged from below detection limits (<0.33 CFU/m^3) to 4.0 CFU/m^3 and total fungi concentrations ranged from below detection limit to 1.3 FU/m^3. A comparison of the pre and post installation bacterial and fungi concentrations (arithmetic average) from each room are summarized in table 1 as the number of microorganisms per m^3 air.

Table 1: Bioaerosol arithmetic average concentrations (# of microorganisms/m^3 air) pre and post installation of the UVGI-HVAC system

Room ID	MB and TA		*S. aureus*		*S. epidermis*		Fungi	
	Pre	Post	Pre	*Post*	*Pre*	*Post*	*Pre*	Post
GW	35.0	16.83	3.0	1.0	<3	0.168	16.0	<0.33
GC	56.0	0.5	9.0	<0.33	13	0.168	6.0	0.333
PW	12.0	0.668	<3.0	<0.33	<3.0	<0.33	<3.0	0.668
PE	39.0	0.168	<3.0	<0.33	<3.0	<0.33	3.0	0.168

MB: Mesophilic bacteria; TA: Thermophilic actinomycetes
<: below detection limits of assay method

Fomites

During pre installation, viable bacteria and fungi were detected on indoor surfaces of both hospital campuses. The fomite concentrations of mesophilic bacteria and thermophilic actinomycetes ranged from below the detection limit (<0.1 CFU/cm^2) to 64 CFU/cm^2. Staphylococci and fungi ranged from below detection limit to 6.4 CFU/cm^2 (*S. aureus*), 37 CFU/cm^2 (*S. epidermis*), and 5.0 FU/cm^2 (fungi). Positive detection of *S. aureus* during pre installation of the UVGI system, suggests that MRSA should be further explored. Microorganisms were comparatively higher during pre installation on surface not commonly touched than on surfaces frequently contacted. Ranges of bacteria and fungi levels as detected on fomites during pre installation are illustrated in table 2. Organism concentration (before and after UV installation) at each location on commonly touched and non-commonly touched surfaces are represented in figure 3 and 4, respectively. Non-touched surfaces represent those sites where material would be accumulating and settling from the air and would not be disturbed nor associated with materials from the hands. In addition, often touched surfaces are not only dynamic surfaces where materials are being laid down and picked up, but are also often cleaned.

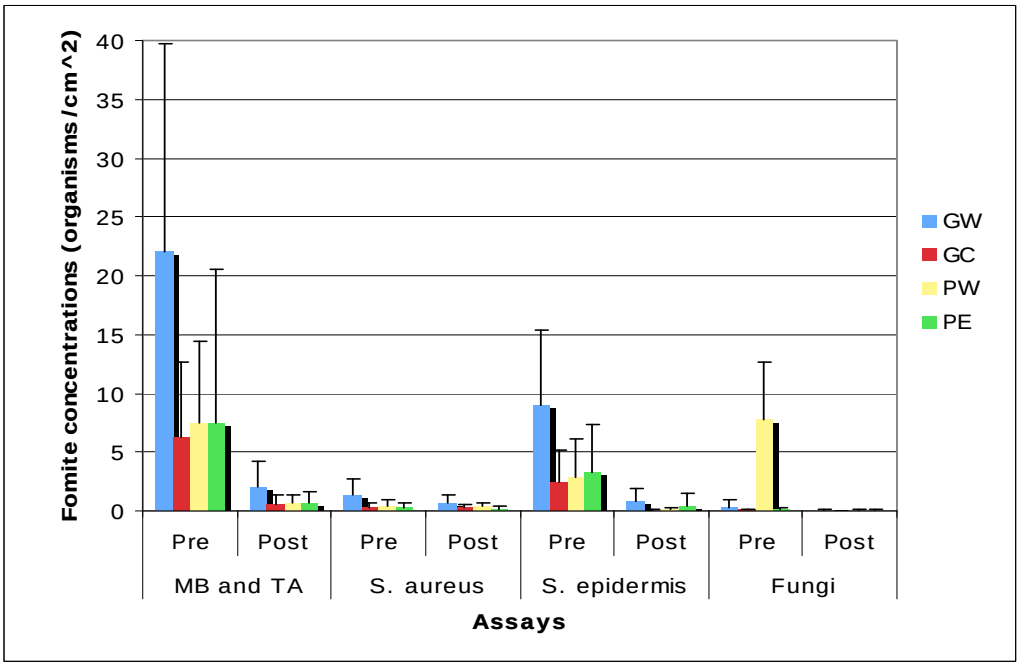

Figure 3: Concentration, organisms/cm^2, of commonly touched surfaces before and after UV system installation

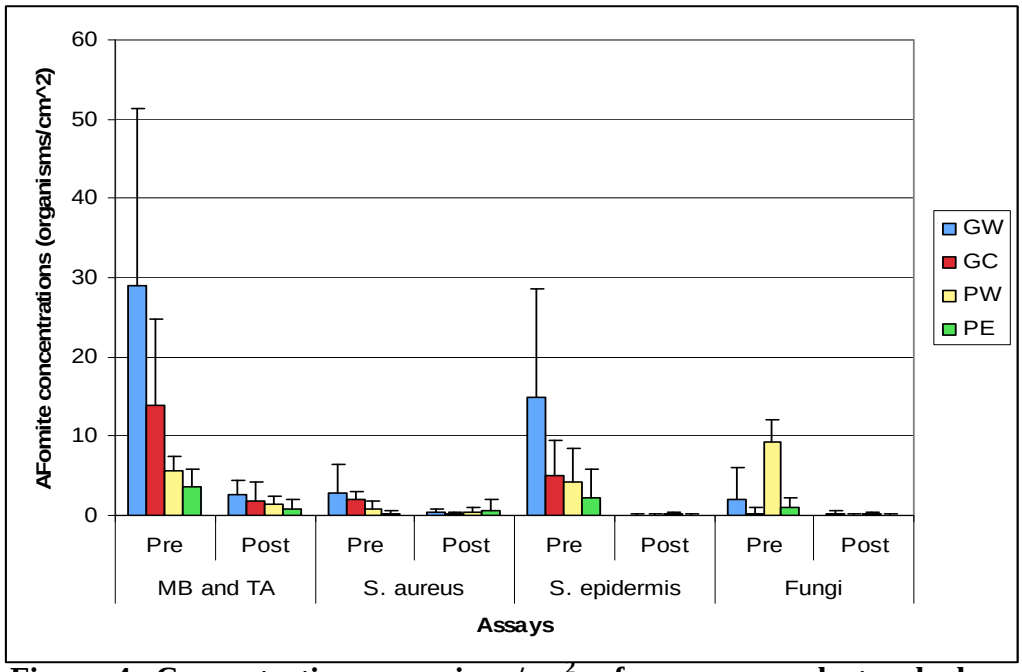

Figure 4: Concentration, organisms/cm^2, of non-commonly touched surfaces before and after UV system installation

Table 2: Fomite average microorganisms/cm^2 on surfaces pre-installation testing

Room ID	Surfaces commonly	MB & TA	*S. aureus*	*S. epidermis*	Fungi
GW	Touched (n = 5)	4.9 – 47 (22±18)	0.4 – 3.6 (1.3±1.4)	2.4 - 17 (9.0±6.4)	<0.1 – 1.7 (0.3±0.7)
	Untouched (n = 5)	3.3 – 64 (29±22)	< 0.1 – 6.4 (2.9±3.6)	0.5 -37 (15±14)	< 0.1 – 9.4 (2.0±4.1)
	Overall (n = 10)	3.3 - 64 (26±19)	< 0.1 – 6.4 (2.1±2.7)	0.5 - 37 (12±11)	< 0.1 – 9.4 (1.2±2.9)
GC	Touched (n = 5)	0.8 - 15 (6.3±6.4)	< 0.1 – 0.9 (0.3±04)	< 0.1 – 5.4 (2.5±2.7)	< 0.1 – 0.3 (0.1±0.1)
	Untouched (n = 5)	5.5 - 30 (14±11)	1.0 – 3.8 (2.1±1.0)	1.0 - 12 (5.1±4.3)	< 0.1 – 1.7 (0.3±0.8)
	Overall (n = 10)	0.8 - 30 (10±9.3)	< 0.1 – 3.8 (1.2±1.2)	< 0.1 - 12 (3.8±3.7)	< 0.1 – 1.7 (0.2±0.5)
PW	Touched (n = 5)	< 0.1 - 17 (7.5±6.9)	< 0.1 – 1.3 (0.4±0.5)	< 0.1 – 7.7 (2.8±3.3)	2.8 - 15 (7.8±4.8)
	Untouched (n = 5)	3.6 – 7.6 (5.6±1.8)	< 0.1 – 2.2 (0.8±1.1)	0.5 - 12 (4.2±4.3)	7.2 - 14 (9.3±2.7)
	Overall (n = 10)	< 0.1 – 7.6 (6.6±4.9)	< 0.1 – 2.2 (0.6±0.9)	< 0.1 - 12 (3.5±3.7)	2.8 - 15 (8.5±3.8)
PE	Touched (n = 5)	0.2 - 31 (7.5±13)	< 0.1 – 0.9 (0.3±0.4)	0.3 – 9.9 (3.3±4.0)	< 0.1 – 0.5 (0.1±0.2)
	Untouched (n = 5)	1.3 – 6.6 (3.7±2.2)	< 0.1 – 0.9 (0.2±0.4)	< 0.1 – 8.3 (2.8±3.6)	< 0.1 – 2.8 (1.0±1.2)
	Overall (n = 10)	0.2 - 31 (5.6±9.0)	< 0.1 – 0.9 (0.2±0.4)	< 0.1 – 9.9 (2.8±3.6)	< 0.1 – 2.8 (0.5±1.0)

GW = Greenlawn campus, emergency department (ED) waiting room,
GC = Greenlawn campus, cardiac intensive care unit (CICU),
PW = Pennsylvania campus, UCC waiting room
PE = Pennsylvania campus, room 1E

During post UVGI installation, viable microorganisms were again detected on surfaces throughout both hospitals (table 3). The MB and TA concentrations detected on commonly touched surfaces ranged from below detection limit (<.05 CFU/cm^2) to 7.9 CFU/cm^2 while non-commonly touched surfaces ranged from below detection limit to 8.9 CFU/cm2. Commonly touched surfaces were found to harbor Staphylococci at ranges below detection limit to 2.6 CFU/cm^2 (*S. aureus*) and below detection limit to 4.5 CFU/cm^2 (*S. epidermis*). The non-commonly touched surfaces ranged from below detection limit to 4.2 CFU/cm^2 (*S. aureus*) and .9 CFU/cm^2 (*S. epidermis*). Fungi were detected at concentrations on commonly touched surfaces (<.05 to .3 CFU/cm2) and non-commonly touched surfaces (<.05 to .7 CFU/cm2).

Table 3: Fomite average # microorganisms/cm^2 on surfaces post installation testing

Room ID	Surfaces commonly	MB and TA	*S. aureus*	*S. epidermis*	Fungi
GW	Touched (n=10)	0.1 - 7.9	<.05 - 2.6	<.05 - 4.5	<.05 - .3
	Untouched (n=10)	0.1 - 6.8	<.05 - 1.3	<.05 - .6	<.05 - .7
	TOTAL (n=20)	0.1 - 7.9	<.05 - 2.6	<.05 - 4.5	<.05 - .7
GC	Touched (n=10)	<.05 - 2.7	<.05 - 1.3	<.05 - .4	<.05 - .2
	Untouched (n=10)	<.05 - 8.9	<.05 - .5	<.05 - .3	<.05 - .4
	TOTAL (n=20)	<.05 - 8.9	<.05 - 1.3	<.05 - .4	<.05 - .4
PW	Touched (n=10)	<.05 - 2.3	<.05 - .9	<.05 - .5	<.05 - .3
	Untouched (n=10)	<.05 - 3.7	<.05 - 1.7	<.05 - .9	<.05 - .5
	TOTAL (n=20)	<.05 - 3.7	<.05 - 1.7	<.05 - .9	<.05 - .5
PE	Touched (n=10)	<.05 - 3.7	<.05 - .7	<.05 - 3.8	<.05 - .2
	Untouched (n=10)	<.05 - 4.3	<.05 - 4.2	<.05 - .3	<.05 - .2
	TOTAL (n=20)	<.05 - 4.3	<.05 - 4.2	<.05 - 3.8	<.05 - .2

GW = Greenlawn campus, emergency department (ED) waiting room
GC = Greenlawn campus, cardiac intensive care unit (CICU)
PW = Pennsylvania campus, UCC waiting room
PE = Pennsylvania campus, room 1E

Methicillin resistant *Staphylococcus aureus (*MRSA) was determined to be of importance during the pre installation testing due to the presence of *S. aureus* on surfaces and in the air. Post installation MRSA analysis was performed on samples that tested positive for the *S. aureus* on MSA medium (n=73). Of these samples, 28 (38%) tested positive for MRSA. MRSA was detected in 33% of the *S. aureus* positive samples on the Greenlawn campus while the Pennsylvania campus tested positive for MRSA in 15 samples (44%). There were no initial

MRSA results from pre installation tests but a decline in post installation concentrations of *S. aureus* may indicate a similar decline in MRSA levels since UV light disrupts DNA and a methicillin resistance would not impact the effectiveness of the UVGI system.

During pre and post installation, bioaerosol levels were slightly higher on the Greenlawn campus when compared to the Pennsylvania campus (Figure 5). As was the case during pre installation testing, total bacterial concentrations exhibited a strong, positive correlation with *S. aureus* concentrations (table 4) after the system had been installed (comparing air and fomite results). Fungi concentrations revealed weak correlations between bacterial levels, suggesting fate and transport of fungi differs from total bacteria and *S. aureus* in the indoor air. Fungi may be entering or proliferating in the air system, and eventually landing on fomites, from damp cooling coils or in drip pans which exist after the ultra violet light in the UVGI system.

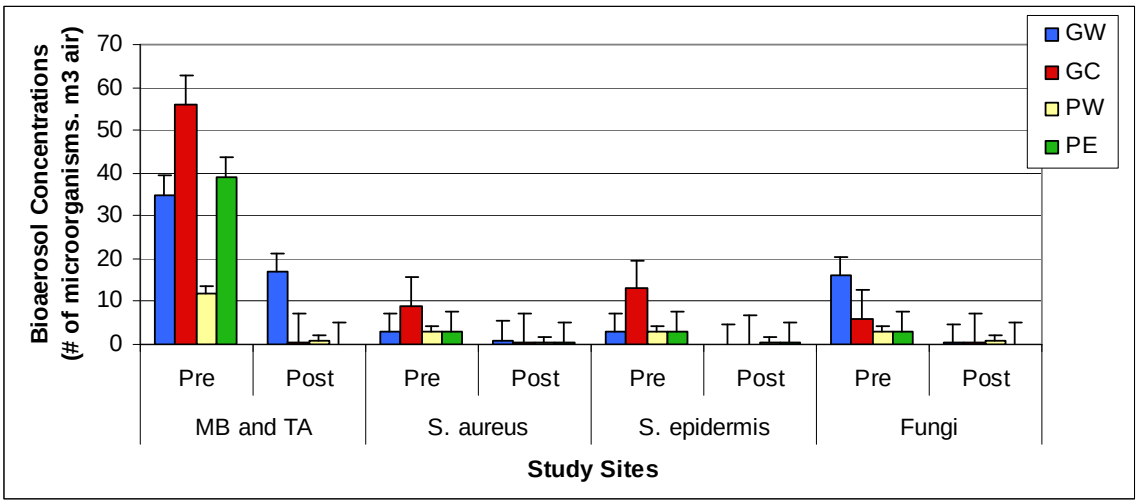

Figure 5: Concentrations of bacteria and fungi in the indoor air during pre and post system installation where MB is Mesophilic bacteria and TA Thermophilic actinomycetes

Table 4: Correlations between microbial concentrations in the indoor air post installation

Room ID	MB and TA	*S. aureus*	*S. epidermis*	Fungi
MB and TA	1.000			
S. aureus	0.999	1.000		
S. epidermis	-0.581	-0.577	1.000	
Fungi	-0.118	-0.141	0.236	1.000

FINAL CONCLUSION

Average levels (organisms/m^3 air) of total bacteria found in the air prior to the UV installation were 45.5 and 25.5, on the Greenlawn campus and Ingham Regional Orthopedic Hospital campus, respectively. Average levels (organisms/m^3 air) of total bacteria found in the air after the UV installation were 8.67 and .418, on the Greenlawn campus and Ingham Regional Orthopedic Hospital campus, respectively. The bacterial concentrations found on fomites were also lower. On all surfaces (commonly and not commonly touched) prior to UV installation, the levels (organisms/cm^3) were 17.9 and 6.1 for the Greenlawn campus and Ingham Regional

Orthopedic Hospital, respectively. On all surfaces (commonly and not commonly touched) after UV installation, the levels (organisms/cm^3) were 1.75 and .85 for the Greenlawn campus and Ingham Regional Orthopedic Hospital, respectively. On both of the campuses of Ingham Regional Hospital, the UV systems appear to have decreased all organism levels in the post installation tests in the air and on non-touched and touched surfaces.

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