Residential Application of the RxAir™ UV Light Portable Air Purification Unit

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Introduction

This report addresses the application of the RxAir™ UV Light Portable Air Purification Unit, formerly known as Eco-Rx and employing the Viratech™ germicidal UV light technology, to residential environments, including houses and apartments. The RxAir unit employs three low-pressure mercury UV lamps each rated for 24 Watts of UV output. The lamps are housed inside a cartridge that is coated with the photocatalyst TiO2, which accelerates the breakdown of organic compounds like VOCs (volatile organic compounds) and reduces the concentration of the odors they cause. Air passes through the cartridge and is disinfected by the UV lamps and the air then flows through a carbon-treated gross particulate capture screen that removes large particles. Airflow is driven through the unit by a 210 cfm fan.

Independent laboratory testing has been conducted to determine the efficacy and safety of the RxAir unit. Inactivation tests on bacteria, viruses, and reduction of odors and VOCs were completed at Northeast Laboratories in Berlin, CT, in accordance with EPA and FDA guidelines. The RxAir UV Light Portable Air Purification unit has a demonstrated ability to disinfect air and inactivate a wide range of bacterial pathogens including *Staphylococcus aureus* (MRSA), *Pseudomonas*, and *Klebsiella* as has been conclusively demonstrated in independent laboratory tests. The RxAir produces a germicidal UV exposure dose of 41 J/m^2, as independently verified by biodosimetric testing, which is sufficient to reduce pathogenic bacterial populations by at least 99%. The UV exposure dose of 41 J/m^2 correlates with a ultraviolet germicidal irradiation (UVGI) Rating Value of URV 15. ETL certification utilizing the UL 507 Standard for Electric Fans was conducted by Intertek Testing Services in Cortland, NY.

In this report the various bacteria, fungi and viruses that may occur inside residences are identified along with their physical characteristics that determine their filterability and UV susceptibility.

Residential Airborne Pathogens

Pathogens in residential homes include viruses and bacteria that come from occupants, including fungal spores that come from the environment and that may grow inside the house, and environmental bacteria. Table 1, Standard Test Array for Air Disinfection Systems, summarizes all the major airborne pathogens that may occur inside houses and apartments, arranged in order from smallest to largest. Table 1 shows the removal rates for UV air disinfection systems rated URV 6 through URV 15. URV stands for UVGI Rating Value and the UV dose ranges for these URV systems are shown in Appendix A, which also provides matching filter recommendations. The RxAir unit qualifies as an URV 15 system and this rating is highlighted in the final column of Table 1. The URV 15 column represents the single-pass removal rates of these pathogens through the RxAir.

The Standard Test Array is used for evaluating the performance of air disinfection systems and includes pathogens likely to occur indoors in homes, but excludes various pathogens that are unique to health care, agriculture, and other non-residential facilities. Included in this list is the emerging pathogen MERS (Middle East Respiratory Syndrome) virus, which is physiologically identical to the Coronavirus (or SARS virus) and which is likely to be just as susceptible to UV irradiation as the Coronavirus, which is here used as a surrogate for UV inactivation.

The average UV rate constant for each of the microbial groups is 0.0742 m^2/J for viruses, 0.1768 m^2/J for bacteria, and 0.0109 m^2/J for fungal spores. These values will be used for the simulation of the model room.

Table 1: Standard Test Array of Residential Pathogens for UV Air Disinfection

Microbe	Type	UVGI k m^2/J	UVGI Removal %							
			URV 6	URV 8	URV 10	URV 11	URV 12	URV 13	URV 14	URV 15
Parvovirus H-1	V	0.09200	7	13	37	60	75	84	94	97
Echovirus 1	V	0.02878	2	4	13	25	35	44	58	68
Coxsackievirus	V	0.11100	8	15	43	67	81	89	96	99
Murine Norovirus (MNV)	V	0.03040	2	4	14	26	37	46	60	70
Reovirus	V	0.00940	1	1	5	9	13	17	25	31
Adenovirus	V	0.03900	3	6	18	32	44	54	69	79
Influenza A virus	V	0.11900	9	16	45	70	83	91	97	99
Avian Influenza virus	V	0.10600	8	15	41	65	80	88	96	99
Coronavirus (SARS)	V	0.01000	1	1	5	10	14	18	26	33
Coronavirus (MERS)	V	0.01000	1	1	5	10	14	18	26	33
Mycoplasma pneumoniae	B	0.27910	19	34	75	94	98	100	100	100
Neisseria catarrhalis	B	0.05233	4	8	23	41	54	65	79	88
Francisella tularensis	B	0.00900	1	1	4	9	13	16	24	30
Newcastle Disease Virus	V	0.14400	10	19	51	76	88	94	99	100
Coxiella burnetii	B	0.15350	11	21	54	78	90	95	99	100
Haemophilus influenzae	B	0.17700	12	23	59	83	93	97	100	100
Proteus vulgaris	B	0.07675	6	11	32	54	68	78	90	95
Vaccinia virus	V	0.16040	11	21	55	80	91	96	99	100
Measles virus	V	0.10510	8	15	41	65	79	88	96	99
Proteus mirabilis	B	0.28900	19	35	76	94	99	100	100	100
Pseudomonas aeruginosa	B	0.57210	35	58	94	100	100	100	100	100
Legionella pneumophila	B	0.19298	13	25	62	85	94	98	100	100
Rickettsia prowazekii	B	0.17600	12	23	59	83	93	97	99	100
Serratia marcescens	B	0.28670	19	35	76	94	99	100	100	100
Mycobacterium tuberculosis	B	0.47210	30	51	91	99	100	100	100	100
Klebsiella pneumoniae	B	0.05480	4	8	24	42	56	67	81	89
Corynebacterium diphtheriae	B	0.07010	5	10	30	50	65	75	88	94
Burkholderia cenocepacia	B	0.03956	3	6	18	33	45	55	69	79
Listeria monocytogenes	B	0.01480	1	2	7	14	20	26	36	45
Yersinia enterocolitica	B	0.15351	11	21	54	78	90	95	99	100
Staphylococcus aureus	B	0.11300	8	16	43	68	82	90	97	99
Staphylococcus epidermis	B	0.16210	11	22	56	80	91	96	99	100
Streptococcus pyogenes	B	0.81100	46	70	98	100	100	100	100	100
Bacillus anthracis spores	BS	0.01988	1	3	9	18	26	33	45	55
Nocardia asteroides	B	0.00822	1	1	4	8	12	15	22	28
Acinetobacter baumannii	B	0.12800	9	17	47	72	85	92	98	99
Enterobacter cloacae	B	0.03598	3	5	16	30	42	51	66	76
Aeromonas	B	0.20310	14	26	64	87	95	98	100	100
Penicillium chrysogenum	FS	0.00434	0	1	2	4	6	8	12	16
Aspergillus niger	FS	0.00058	0	0	0	1	1	1	2	2
Candida albicans	F	0.00515	0	1	3	5	7	10	14	19
Cryptococcus neoformans	FS	0.01670	1	2	8	15	22	28	39	49
Trichophyton rubrum	FS	0.00411	0	1	2	4	6	8	12	15
Clostridium tetani	B	0.04699	3	7	21	37	51	61	76	85
Stachybotrys chartarum	FS	0.00041	0	0	0	0	1	1	1	2
Scopulariopsis brevicaulis	FS	0.00344	0	1	2	3	5	7	10	13
Ustilago zeae	FS	0.06580	5	9	28	48	63	73	86	93
Rhizopus nigricans	FS	0.00861	1	1	4	8	12	16	23	29
Mucor mucedo	FS	0.00384	0	1	2	4	6	7	11	14
Cladosporium herbarum	FS	0.00370	0	1	2	4	5	7	11	14
Blastomyces dermatitidis	F	0.01645	1	2	8	15	22	28	39	48
Fusarium oxysporum	FS	0.00886	1	1	4	8	12	16	23	30

NOTES: B: Bacteria, BS: Bacterial Spore, V: Virus, F: Fungi, FS: Fungal Spore

A Model Residential Room

In order to evaluate the performance of the RxAir, and other air disinfection units, it is necessary to define a model residential room that includes standard airflow characteristics. Typical modern houses and apartments include forced air ventilation that may result in several air changes per hour. Naturally ventilated houses have unknown airflow rates that depend on the wind, leakage, and number of open windows. In this report we only address houses with forced ventilation.

Assuming that the model room has 210 sq. ft. of floor area, we would expect a typical forced air system to provide about 4 air changes per hour. With an 8 foot ceiling this equates to a volume of 1680 cu.ft. (47.6 m^3) and there will be 4 x 47.6 = 190 m^3 per hour of air exchanged or 3.17 m^3/min (112 cfm). A nominal outside air of 25% produces 28 cfm of fresh air. The RxAir unit has an airflow of 210 cfm or 5.95 m^3/min for an ACH of 7.5. Figure 1 illustrates the model room with a RxAir placed inside.

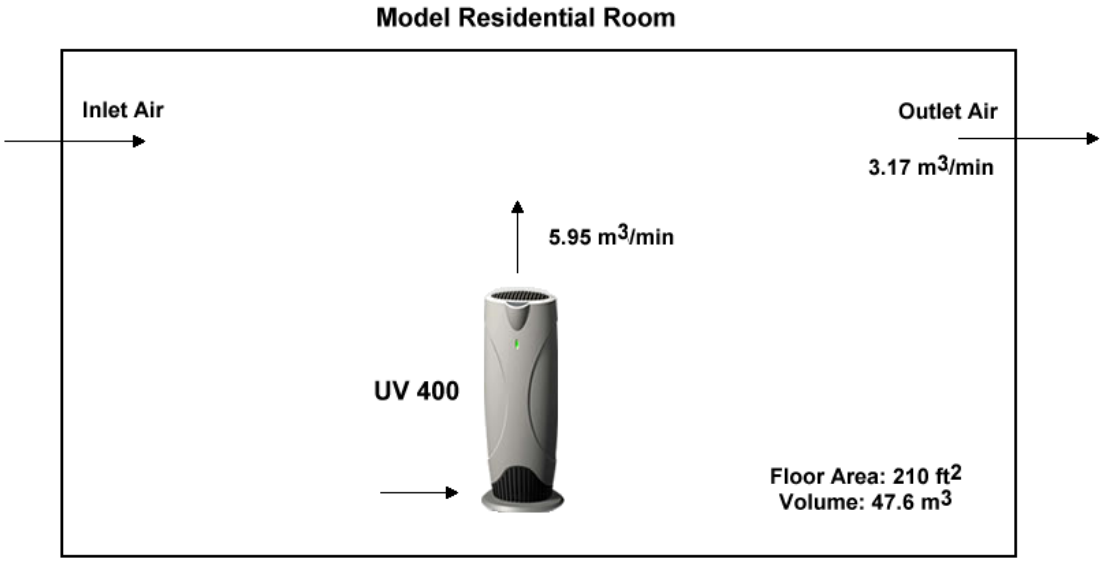

Figure 1: A model residential room with 210 ft^2 of floor area and an 8 ft ceiling.

In order to determine how well the RxAir unit performs in this model environment it is necessary to assume some initial level of microbial contamination in the air, both inside and outside. Indoor microbial contamination hails from the occupants, pets, and from accumulated mold spores that may be embedded in rugs and furnishings or that may be growing in damp areas or in ducts. Outdoor contamination consists of fungal spores and environmental bacteria that are brought in with the outdoor air.

Let us assume an initial concentration of 1000 cfu/m^3 of bacteria and 1000 cfu/m^3 of fungal spores. These values are similar to actual measured values

inside homes and the bacterial value is a suggested upper limit for indoor contamination (Kowalski 2003).

For the Outside Air model, let us assume 25% of the outside air is fresh and the rest recirculated. We will assume that outdoor air had 600 cfu/m^3 of fungal spores and 100 cfu/m^3 of environmental bacteria. There are no viruses in the outdoor air. We will also assume that Table 1 represents the mixture of indoor pathogens and that the bacteria and fungi in Table 1 represents the mixture of outdoor microbes.

Table 2 summarizes the input data for the residential room model, including input data for the full recirculation model (no outside air) and the simulation with a total room airflow (not counting the RxAir) of 112 cfm and 25% outside air.

Table 2: Input Data for Residential Room Model

Viratech UV 400	UV Dose	41	J/m^2
	Airflow	5.94657	m^3/min
	Airflow	210	cfm
	ACH	7.5	
Model Room	Floor Area	210	ft2
	Height	8	ft
	Volume	1680	ft3
	Volume	47.6	m^3
	Total Airflow	112	cfm
	Total Airflow	3.171504	m^3/min
	OA %	25	
	OA Flowrate	28	cfm
	OA Flowrate	0.792876	m^3/min
	ACH	4	
	OA ACH	1.0	
Indoor Microbes (Initial Concentration)	Bacteria	1000	cfu/m^3
	Viruses	10,000	cfu/m^3
	Fungi	1000	cfu/m^3
Outdoor Microbes	Bacteria	100	cfu/m^3
	Viruses	0	cfu/m^3
	Fungi	600	cfu/m^3
Average k Value	Bacteria	0.1768	m^2/J
	Viruses	0.0742	m^2/J
	Fungi	0.0109	m^2/J
Average Kill Rate (UV 400 Single Pass)	Bacteria	99.9	%
	Viruses	95.2	%
	Fungi	36.1	%

Two simulations will be performed using the RxAir unit operating in the room, one without any outside air, and one with outside airflows as detailed in Table 2.

In-Place Performance in a Model Residential Room

Table 2 shows the input data for the first room model, in which there is no outside air and the air cleaning is entirely performed by the RxAir unit. It is also assumed the rooms are unoccupied and no internal generation of microbes occurs. A minute-by-minute analysis was performed using the assumption of complete mixing of air, which is reasonable for open areas.

Results show the initial microbial concentrations are reduced to zero within about 3 hours. Figure 2 illustrates the rate at which airborne microbial concentrations are reduced over time for each of the three microbial groups. The summation of the three groups, the Total Microbes, decreases to unitary values after about 2.5 hours. Bacteria and viruses are removed at similar rates while the hardier fungal spores are removed more slowly due to their inherent resistance to UV irradiation. Because the air is exchanged through the RxAir at about 7.5 air changes per hour, fungal spores may experience some 20 passes through the unit after 2.5 hours and this is sufficient to reduce their population to single digits.

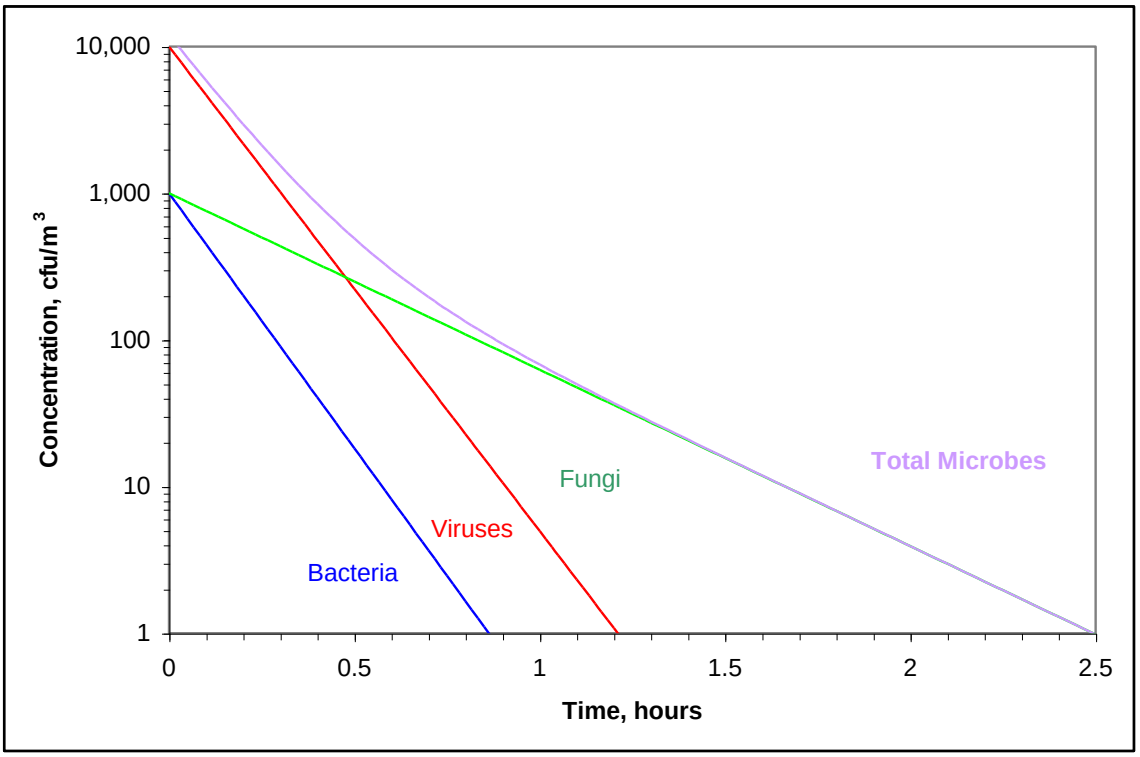

Figure 2: In-place performance of the RxAir in a 210 ft^2 room with no outside air and initial concentrations of microbes as indicated.

The previous simulation ignored the addition of microbes to the room, which may occur from outside air and building leakage, and also from occupants and internal generation of mold spores (i.e. in problem buildings). In the next simulation it is assumed that the outside air contains environmental bacteria and fungal spores that are brought into the room unfiltered. With 112 cfm total airflow assumed and 25% outside air, this equates to 28 cfm of fresh air.

Figure 3 illustrates the results of the model room simulation. Since fungi and bacteria are continually being added to the room form unfiltered outside air, there is a steady-state limit to which indoor levels can be reduced. The steady-state condition will leave about 13 cfu/m^3 of bacteria and 222 cfu/m^3 of fungi, neither of which are considered hazardous levels. Since no viruses come from outdoor air, these values are reduced to unitary values from the initial condition.

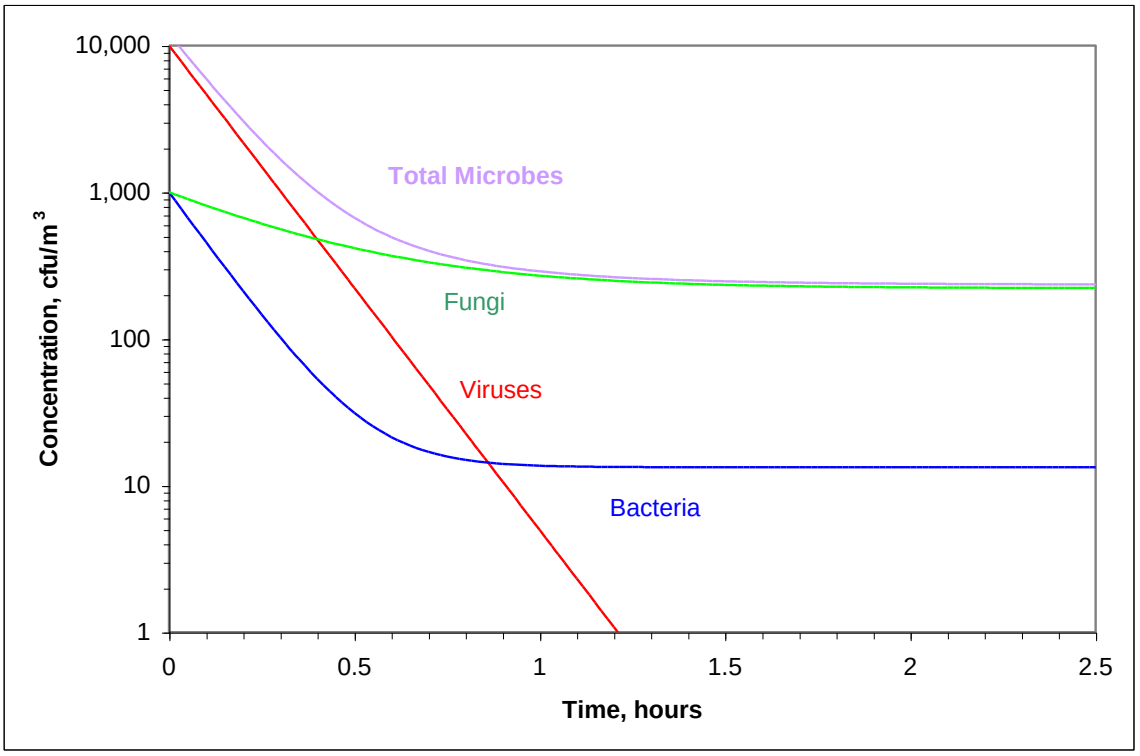

Figure 3: In-place performance of the RxAir in a 210 ft^2 room with 25% outside air and initial concentrations of microbes as indicated.

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