GELT INTERNATIONAL S.R.L.
Via Andrea Costa 228
40134 BO Italia
CF/P. IVA 03650351202
Cap. Sociale € 10.000,00 i.v.
Registro Imprese di Bologna
REA 535891

Germicidal irradiation assessment of the UV-C device “SanificaAria 30”

BEGHELLI SPA

Contact person:
Chiara Piana, PhD
c.piana@geltinternational.it

Issuing date:
14/07/2020

Revision:
20TR0026/01

SUMMARY

1. FOREWORD

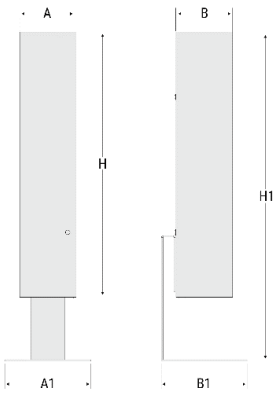
The Beghelli Group is leader in Italy and Europe in the emergency lighting market; the Beghelli group also operates in the field of energy saving lighting, electronic systems for domestic and industrial safety and photovoltaic power production.

To reduce contaminating agents from the air without interfering with people's habits, Beghelli decided to use a technology that replicates the natural purifying action of the solar radiation, reducing or eliminating any microbiological contaminating substances. From the observation of nature uvOxy® was born, i.e. an environmental sanitization system that bases its technology on a flow cell internally illuminated by a UV-C source. The forced circulation of the air through this cell is sanitizing the air itself, maintaining the process always effective and respectful of the environment and people. Light is the only element needed, Beghelli has been using it for years for the safety and comfort of people.

In particular, the Beghelli's R&D area is developing several devices that are using UV-C light to treat the air.

2. SCOPE OF THE TEST

Beghelli developed a system called SanificaAria 30 with the technical features listed in figure 1.



TECHNICAL FEATURES SanificaAria 30
Power supply: 230Vac ±10%, 50÷60Hz
Local switch on the power cord
Absorption: 24W
UV-C Lamp: TC 2G11 18W
Wave length UV-C: 254nm
Sanitization airflow rate: 30m^3/h
Radiant power UV-C: 5,5W
Ozone Free UV-C Lamp
Cartridge life: 12 months
Noise level: 40dB(A) at 1 meter
Weight: 3,5kg
The product can be classified as an air purifier according to the norm IEC 60335-2-65 'Household and similar electrical appliance - safety - part 2-65 particular requirements for air cleaning appliances'

Dimensions mm						Sanitization airflow rate
A	B	H	A1	B1	H1	
100	100	475	152	152	584	30 m^3/h

Figure 1: SanificaAria 30 air sanitizing device by Beghelli. The filtering and sanitizing module consists of an axial fan suction system that introduces air into the closed chamber which contains the UV-C source, where the sanitization process is carried out. System dimensions and airflow rate are reported, as well as the technical features provided by the manufacturer.

The scope of this project is to assess the germicidal activity of the device against microorganisms that differ from each other in terms of resistance to UV-C light itself.

3. MATERIALS AND METHOD

3.1 Materials and instrumentation

The test is performed following the prescriptions, as applicable, of the technical norm ISO 15714: 2019 *Method of evaluating the UV dose to airborne microorganisms transiting in-duct ultraviolet germicidal irradiation devices*. The norm describes a method in laboratory to assess the performance of ultraviolet germicidal irradiation (UVGI) devices which will be mounted in-duct in heating, ventilating and air-conditioning (HVAC) systems.

As in the systems described by ISO 15714: 2019, this Beghelli device is equipped with suction fans to force air into the system, it has a duct in which the air passes through a UV-C lamp and a fan that pushes the treated air outwards.

Unlike what is described in the technical norm, the Beghelli system has particularly small dimensions compared to the HVAC systems, therefore also the test rig is proportionally reduced. In any case, the test is carried out as described in the norm, i.e. inoculating microorganisms before the UV lamp and collecting them after the UV lamp (figure 2).

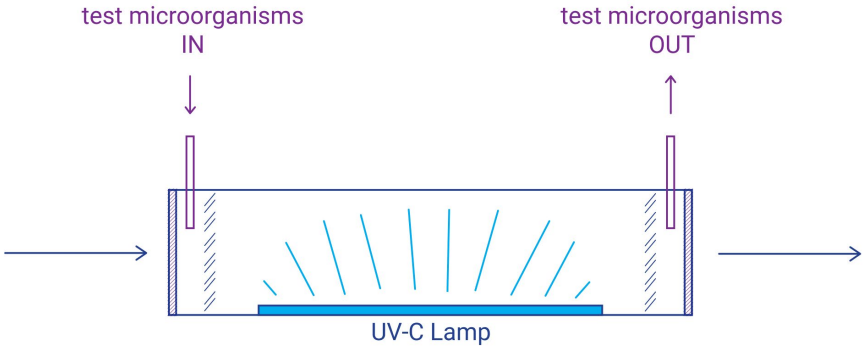


Figure 2: diagram of the test rig. Microorganisms are inoculated upstream of the UV-C lamp (IN) and collected downstream of the lamp (OUT).

The microorganisms described at chapter 6 of the norm are used for the test, and they are listed in table 1.

Table 1: test microorganisms, as per chapter 6 of the ISO norm.

TEST MICROORGANISM	GROUP	DOSE D90* (J/m²)
Serratia marcescens ATCC 13880	Gram negative bacteria	< 25
Bacillus subtilis ATCC 6633	Gram positive bacteria	25 ÷ 120
Cladosporium sphaerospermum ATCC 11289	Fungus	> 120

* UV-C effective dose necessary for the inactivation of the 90% of the microorganisms.

Microorganisms are collected after the UV lamp both with the lamp off (as a control reference) and with the lamp on (as a result of the germicidal system). Each of the two tests is performed in triple, with an acceptability of relative differences less than 50% (paragraph 7.3.2 of ISO 15714: 2019). The lamp is preheated for 15 minutes before the collection of microorganisms, as per paragraph 7.3.1.

The test flow rate is adjusted on the basis of the commercial characteristics of the Beghelli device, rather than those suggested by the standard, since they are more realistic for the actual use of the system.

For the test, a lamp with already 100 hours of operation is used (burn-in time, as per paragraph 4.6 of ISO 15714: 2019).

A prototype is used for the test and it differs from the commercial system for the absence of a reflective internal part (see sketch 2 of figure 3). This makes the germicidal activity of the prototype less efficient since the UV-C light is not reflected by the walls, amplifying its power.

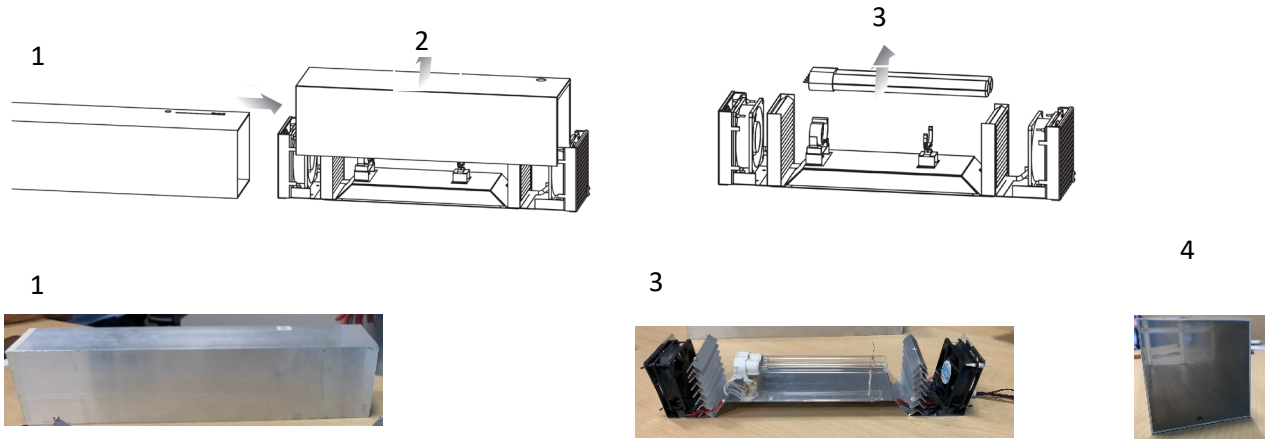


Figure 3: Top line: schematic representation of the commercial SanificaAria 30 system: *1)* external casing in satin metal; *2)* internal protection in reflective polished metal; *3)* internal UV-C lamp**. Bottom line:** test prototype: *1)* external casing in satin metal as the commercial device; *2)* missing part (the internal reflective protection available only in the commercial device); *3)* internal UV-C lamp as the commercial device; *4)* view of the inner part of the non-reflective outer casing as per part 1.

3.2 Analytical procedure

The analyses are carried out at the UNI CEI EN ISO / IEC 17025: 2005 accredited laboratory Tecnal srl, in collaboration with Gelt International srl, between 12/06/2020 and 13/07/2020.

The test microorganisms are introduced into a nebulizer and conveyed in front of the intake fan of the airflow of the SanificaAria 30. A SAS suction pump is placed at 10 cm from the treated air outlet for the collection of microorganisms. SAS plates are then incubated for subsequent colony counts. Figure 4 represents the test rig.

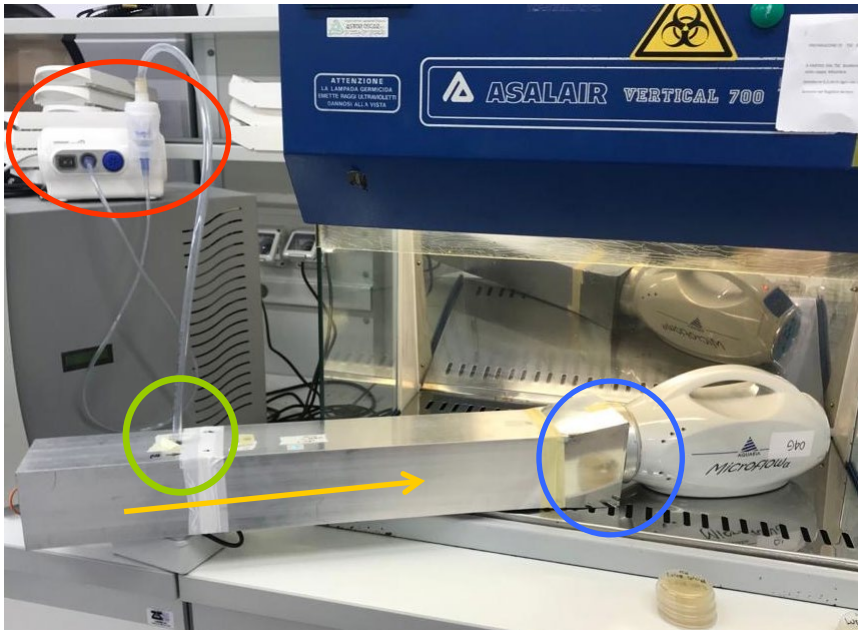


Figure 4: SanificaAria 30 test rig. The microorganisms are filled into a nebulizer (in red) and conveyed to the system (in green) upstream of the air flow (indicated by the yellow arrow), then collected with SAS on a plate (in blue).

At the end of the analysis, the germicidal activity is calculated as inactivation rate, expressed as:

$$N_0/N\ (\%)$$

or

$$\log\ (N_0/N)$$

in which

N_0 = number of viable bacteria recovered (in CFU) at the exit of the SanificaAria30 system with the lamp off

N = number of viable bacteria recovered (in CFU) at the exit of the SanificaAria30 system with the lamp on

The tests are carried out by setting the SAS pump at the same flow rate as the system to avoid influences to its fluid-dynamics (30 m^3/h), in a microbiologically controlled environment with a temperature of 26.1 ° C and a relative humidity of 38%.

Different volumes of air (10, 100 and 1.000 litres) are collected as setting of the most suitable concentration of microorganisms (as required by paragraph 7.3.1 of the norm).

4 RESULTS

The test results for the analysis of *Serratia marcenscens* are shown in Table 2.

	Colonies with lamp off			Colonies with lamp on		
	CFU at 10L	CFU at 100L	CFU at 1000L	CFU at 10L	CFU at 100L	CFU at 1000L
Test 1	3000	1600	NC	0	60	9
Test 2	2600	1300	NC	0	30	13
Test 3	5500*	1400	NC	0	50	11
Mean value	2800*	1433	NC	0	47	11

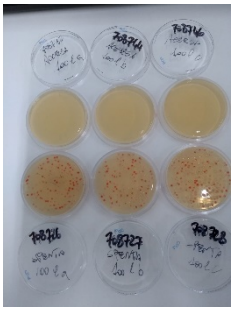
Table 2: Test results with *Serratia marcenscens* with UV-C lamp switched off and with UV-C lamp switched on, each test in triplicate, collecting on the plates a volume of air of 10, 100 and 1000 litres with SAS pump placed at the outlet of the air treated by SanificaAria 30 Beghelli. NC: uncountable. Certificate of analysis as attachment.

* The datum of the third test is discarded in the calculation of the mean value since the relative difference with the other data is bigger than 50% (requirement reported at point 7.3.2 of ISO 15714: 2019).

Therefore the inactivation rate is:

N_0/N (%) = 99,9 % (calculation from the 10 litres of treated air data)

N_0/N (%) = 96,7 % (calculation from the 100 litres of treated air data)



The test results for the analysis of *Bacillus subtilis* are shown in Table 3.

	Colonies with lamp off			Colonies with lamp on		
	CFU at 10L	CFU at 100L	CFU at 1000L	CFU at 10L	CFU at 100L	CFU at 1000L
Test 1	900	720	NC	300	80	130
Test 2	900	770	NC	0	140	118
Test 3	1100	840	NC	0	150	106
Mean value	967	777	NC	100	123	118

Table 3: Test results with *Bacillus subtilis* with UV-C lamp switched off and with UV-C lamp switched on, each test in triplicate, collecting on the plates a volume of air of 10, 100 and 1000 litres with SAS pump placed at the outlet of the air treated by SanificaAria 30 Beghelli. NC: uncountable. Certificate of analysis as attachment.

Therefore the inactivation rate is:

N_0/N (%) = 89,7 % (calculation from the 10 litres of treated air data)

N_0/N (%) = 84,1 % (calculation from the 100 litres of treated air data)

The test results for the analysis of *Cladosporium sphaerospermum* are shown in Table 4.

	Colonies with lamp off			Colonies with lamp on		
	CFU at 10L	CFU at 100L	CFU at 1000L	CFU at 10L	CFU at 100L	CFU at 1000L
Test 1	4000	1700	NC	3500	1000	NC
Test 2	7700*	1600	NC	3000	1200	NC
Test 3	4500	1600	NC	3300	540**	NC
Mean value	4250*	1633	NC	3267	1100**	NC

Table 4: Test results with *Cladosporium sphaerospermum* with UV-C lamp switched off and with UV-C lamp switched on, each test in triplicate, collecting on the plates a volume of air of 10, 100 and 1000 litres with SAS pump placed at the outlet of the air treated by SanificaAria 30 Beghelli. NC: uncountable. Certificate of analysis as attachment.

* The datum of the second test is discarded in the calculation of the mean value since the relative difference with the other data is bigger than 50% (requirement reported at point 7.3.2 of ISO 15714: 2019).

** The datum of the third test is discarded in the calculation of the mean value since the relative difference with the other data is bigger than 50% (requirement reported at point 7.3.2 of ISO 15714: 2019).

Therefore the inactivation rate is:

N_0/N (%) = 23,1 % (calculation from the 10 litres of treated air data)

N_0/N (%) = 32,7 % (calculation from the 100 litres of treated air data)

5 CONCLUSIONS

The ISO 15714: 2019 technical standard reports that the different test microorganisms show different resistance to UV-C light (paragraph 6) by requiring UV doses of

- < 25 J/m^2 for *Serratia marcenscens*,
- between 25 and 120 J/m^2 for *Bacillus subtilis*,
- > 120 J/m^2 for *Cladosporium sphaerospermum*

The results of the present study confirm that the SanificaAria 30 device by Beghelli has an effective UV-C dose between 25 and 120 J / m^2, inactivating up to 90% of the Gram positive microorganisms and up to 99% of the Gram negative test microorganisms. The test fungus, *Cladosporium sphaerospermum*, is inactivated no more than 33% since it would actually require higher UV doses.

The Annex C of the ISO 15714: 2019 reports a long list of scientific literature data relating to the UV-C doses (D90) required to inactivate the 90% of different microorganisms, bacteria, viruses, fungi and others. On the basis of the data obtained from the laboratory tests which show a proven ability of the SanificaAria 30 system to express an effective D90 dose of about 120 J/m^2, it is possible to point out a list of microorganisms which, theoretically and on the basis of these literature data, can be inactivated by the same system (underlined in green in table 5).

Table 5: Data listed in Table C.1 of ISO 15714: 2019 in Annex C. The microorganisms with a dose D90 <120 J / m^2 are underlined in green, while those with a dose D90> 120 J / m2 are underlined in red.

Type	Microorganism	State	*k* m2/J	D90 J/m2	Source
Bacteria	B. atrophaeus (B. globigii)	Sp	0,016	144	EPA (2006)
	Bacillus subtilis	Veg	0,168 58	14	Nakamura (1987)
	Bacillus subtilis spores	Sp	0,026	89	Peccia (2001)
	Bacillus subtilis spores	Sp	0,015 5	149	Ke (2009)
	Bacillus subtilis spores	Sp	0,027	85	Peccia (2001)
	Burkholderia cepacia	Veg	0,211 5	11	Fletcher (2004)
	Burkholderia cepacia	Veg	0,105 2	22	Fletcher (2004)
	Escherichia coli	Veg	0,723	3	Webb (1970)
	Escherichia coli	Veg	0,218	11	Webb (1970)
	Escherichia coli	Veg	0,219	11	Rentschler (1942)
	Escherichia coli	Veg	0,181	13	Rentschler (1942)
	Escherichia coli	Veg	0,156 11	15	Luckiesh (1949)
	Escherichia coli	Veg	0,965	2	Koller (1939)
	Escherichia coli	Veg	0,205	11	Koller (1939)
	Francisella tularensis	Veg	0,009	256	Beebe (1959)
	Francisella tularensis	Veg	0,008	288	Beebe (1959)
	Mycobacterium bovis BCG	Veg	0,242	10	Riley (1976)
	Mycobacterium bovis BCG	Veg	0,19	12	Peccia (2002)
	Mycobacterium bovis BCG	Veg	0,12	19	Ko (2000)
	Mycobacterium bovis BCG	Veg	0,07	33	Ko (2000)
	Mycobacterium parafortuitum	Veg	0,18	13	Peccia (2001)
	Mycobacterium parafortuitum	Veg	0,05	46	Peccia (2001)
	Mycobacterium parafortuitum	Veg	0,12	19	Xu (2003)
	Mycobacterium phlei	Veg	0,036 5	63	Riley (1976)
	Mycobacterium phlei	Veg	0,1	23	Kethley (1973)
	Mycobacterium phlei	Veg	0,14	16	Gillis (1974)
	Mycobacterium smegmatis	Veg	0,19	12	Gillis (1974)
	Mycobacterium tuberculosis	Veg	0,472 1	5	Riley (1976)
	Pseudomonas aeruginosa	Veg	0,572 1	4	Sharp (1940)
	Pseudomonas fluorescens	Veg	0,477 3	3	VanOsdell (2002)
	Serratia indica	Veg	0,011	209	Harstad (1954)
	Serratia marcescens	Veg	0,939	2	Fletcher (2003)
	Serratia marcescens	Veg	0,095	24	Fletcher (2003)
	Serratia marcescens	Veg	0,286 7	8	UVDI (2001)
	Serratia marcescens	Veg	0,575	4	Ko (2000)
	Serratia marcescens	Veg	0,02	115	Ko (2000)
	Serratia marcescens	Veg	0,444 9	5	Sharp (1940)
	Serratia marcescens	Veg	0,113	20	Nakamura (1987)
	Serratia marcescens	Veg	0,07	33	Peccia (2001)
	Serratia marcescens	Veg	0,92	3	Lai (2004)
	Serratia marcescens	Veg	0,430 5	3	VanOsdell (2002)
	Serratia marcescens	Veg	0,45	5	Peccia (2001)
	Serratia marcescens	Veg	2,2	1	Lai (2004)
	Staphylococcus albus (1)	Veg	0,099 5	23	Rentschler (1942)
	Staphylococcus albus (2)	Veg	0,044	52	Rentschler (1942)
	Staphylococcus aureus	Veg	0,113	20	Nakamura (1987)
	Staphylococcus aureus	Veg	0,347 6	7	Sharp (1940)
	Staphylococcus aureus	Veg	0,960 2	2	Luckiesh (1949)

	Staphylococcus aureus	Veg	0,962	2	Luckiesh (1946)
	Staphylococcus epidermis	Veg	0,162 1	14	VanOsdell (2002)
	Staphylococcus epidermis	Veg	0,008	29	VanOsdell (2002)
	Staphylococcus epidermis	Veg	0,113	20	Nakamura (1987)
	Streptococcus agalactiae	Veg	0,434 2	5	Luckiesh (1949)
	Streptococcus pyogenes	Veg	1,561	1	Luckiesh (1949)

Virus	Adenovirus	dsDNA	0,068	34	Walker (2007)
	Adenovirus	dsDNA	0,039	59	Walker (2007)
	Adenovirus	dsDNA	0,055	42	Jensen (1964)
	Bacteriophage MS2	ssRNA	0,048	26	Walker (2007)
	Bacteriophage MS2	ssRNA	0,038	61	Walker (2007)
	Bacteriophage MS2	ssRNA	0,81	3	Tseng (2005)
	Bacteriophage MS2	ssRNA	0,64	4	Tseng (2005)
	Coliphage öX-174	ssDNA	0,71	3	Tseng (2005)
	Coliphage öX-174	ssDNA	0,53	4	Tseng (2005)
	Coliphage T7	dsDNA	0,33	7	Tseng (2005)
	Coliphage T7	dsDNA	0,22	10	Tseng (2005)
	Coronavirus	ssRNA	0,377	3	Walker (2007)
	Coxsackievirus	ssRNA	0,111	21	Jensen (1964)
	phage phi 6	dsRNA	0,43	5	Tseng (2005)
	phage phi 6	dsRNA	0,31	7	Tseng (2005)
	Sindbis virus	ssRNA	0,104	22	Jensen (1964)
	Vaccinia virus	dsDNA	2,54	1	McDevitt (2007)
	Vaccinia virus	dsDNA	0,153	15	Jensen (1964)

Fungi and Others	Aspergillus amstelodami	Sp	0,003 44	669	Luckiesh (1949)
	Aspergillus niger	Sp	0,000 58	398 4	Luckiesh (1949)
	Aspergillus versicolor	Sp	0,006	384	VanOsdell (2002)
	Aspergillus versicolor	Sp	0,003	768	VanOsdell (2002)
	Aspergillus versicolor	Sp	0,016 6	139	VanOsdell (2002)
	Aspergillus versicolor	Veg	0,024	96	Nakamura (1987)
	Cladosporium herbarum	Sp	0,003 7	622	Luckiesh (1949)
	C. sphaerospermum	Sp	0,002 1	143 9	VanOsdell (2002)
	Mucor mucedo	Sp	0,003 99	577	Luckiesh (1949)
	Penicillium chrysogenum	Sp	0,001 8	164 5	VanOsdell (2002)
	Penicillium chrysogenum	Sp	0,004 34	531	Luckiesh (1949)
	Rhizopus nigricans	Sp	0,008 61	267	Luckiesh (1949)
	Scopulariopsis brevicaulis	Sp	0,003 44	289 0	Luckiesh (1949)
	Torula sphaerica	VegY	0,099 86	23	Luckiesh (1949)

Dr. Chiara Piana