Questions Received to the IUVA Webinar
"Expert Perspectives on UV as a Tool for N95 Decontamination"
14 May 2020

Go to Responses

Questions Received during the N95 UV Decontamination Webinar	Resp. #
UVC lights are known to generate ozone, is this a problem?	37
I did a proposal to our city mayor using UV-C for decontamination on masks. They selected ozone technics instead saying that UV-C didn't clean inside the layers of the masks but only on surface... Any documents that shows that the full decontamination. Works well for masks? As good as ozone technics?	1
UV has been suggested as a method for disinfecting surfaces, especially in hospitals. How does it compare with more traditional methods including various chemical sprays? Is there any experience to suggest typical irradiance levels and exposure times?	5
What is the irradiance for these charts in mW/cm^2?	21
The shadowing effect is a concern because most people don't understand the concept. Can you help everyone understand the point of concern?	51
And would increasing irradiance improve the disinfection through mask layers?	54
Does the FDA & CDC accept testing results from outside accredited S3 independent laboratories.	30
Does UV affect the electrostatic layers of the mask?	46
In testing the masks, would droplet application significantly affect the masks which we want to test, say relative to aerosolizing application?	31
[Q for Barry.] What impact does the UV light have on the electrostatic fibers?	46
Do all N95s have the hydrophobic outside layer or only surgical FDA cleared N95s?	47

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Also, literature shows usage of MS2 phage in mask decon. where we saw 1-2mJ/cm² for 3log reduction. What is the most appropriate surrogate for the current COVID-19 testing, given that MS2 seems more resistant to UV compared to COVID-19, and testing with it could be overkill	32
Can you cover all of the concerns related to fake respirators and inappropriate marking for international sale?	4
How do you test the effectiveness of UVC in cleaning N95? What is the UVC irradiance and dose?	33
Do UV Hg lamps ionize the air such that it could mitigate the electrostatic charges in the mask?	46
Dr Brenner of Columbia U reports Far UV 222 nm light being more effective at lower doses. Does anyone on this webinar have info on 222 nm Far UVc?	28
Has anyone looked at highly diffuse reflective media in disinfection chambers to improve the disinfection of these masks?	52
What are your recommendations to measure UV dose correctly?	43
Has anyone used a 187nm wavelength lamp in an enclosed chamber for mask decontamination or has all the testing been done with 254nm only?	27
Applying high UV doses, wouldn't that cause the temperature to rise too much?	50
What is the origin of organism response plateau at high doses? Is this a real effect or measurement artifact?	12
Do we know if there are any labs currently testing with UVC on N95 material with the Cov-2 inoculum?	13
Is there somewhere that you can link all of the information for us to look at again?	56
Is there a trend to use lamps over LEDs for masks?	14
Recommendations on chemical dosimeters?	44
How about efficacy of far-UV 222nm, or combination of 222nm & 254nm? Thanks!	26
Should microbial testing for device effectiveness be limited to only SARS type viruses? Should the testing not expand to other microbes in a healthcare facility, which might require a higher dosage?	34
We have the D90 of Covid-19	15
Accurate dosimetry seems to be an issue, hearing from NIST that measurements can vary by up to 50% for different calibrated systems. How good are the chemical dosimeters and how do we know that?	44
instead of UV, can we spray alcohol on the mask to decontaminate it?	1

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Is there a national standard for measurement of UVGI?	45
Do we have any chemical dosimeters to ascertain dose at this level of irradiance?	44
Can you comment on the limiting factors contributing to why a UVGI N95 reprocessing technology has not yet received an FDA EUA?	35
Several times shadowing has been mentioned but no recommendation has followed on how best to handle this. Most devices being introduced work with masks laid out or hung in a stable/fixed position. Is there a recommendation on how to handle shadowing with these devices?	51
Are CPAP UVC disinfector units effective in disinfecting N95 masks?	7
Is the dose required for surface disinfection is the same dose required for water disinfection, or is there a different calculation for the two?	16
What is the size of a small and large droplet?	2
If UV decontamination is primarily a short-term stop gap, is the stop gap currently being fulfilled by existing vendors today? And does the ability to produce the correct supply of new masks eliminate the need for UV decontamination of N95 masks.	4
Does ECRI have recommendations on determining when a device no longer delivers the target dose and lamps have to be replaced?	57
What is the UVT through each droplet? Is it modelled after water with 90% UVT or virion embedded in 1% serum?	39
We are having a challenge getting the inoculum to stay on the mask material. we need to have 7 or 8 or 9 log applied to the masks so we can prove 6 log reduction...having challenge getting that amount applied before the UVC treatment...	40
'@ ESRI & Mareid: Are there currently any UV "decontamination" devices available for clinicians in private practice, and not practicing in large institutional settings. Thank you. GREAT talk by all!	9
Richard, have you seen the Terminator CoV conveyor system for high volume, high dosage? 700 masks per hour....	11
Regarding the shadowing issue, are there practical solutions to mitigate this risk in a real-world setting?	51
The latter is the protocol baseline for challenging 254nm or 272 nm of inoculate on glass slide	41
Can UVC be used in commercial HVAC system to treat air?	6
If the virus can be spread through airborne particles, and the size of the virus is similar to that of tobacco smoke, why is there a 'safe zone' beyond 6 feet?	2

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Shouldn't we be focusing on air disinfection using UVC?	6
Can forced air supplied from the face-side be used in combination with UV, simultaneously or sequentially, to assist in dislodging/expelling droplets from the internal fibers?	53
What about the standard https://www.astm.org/Standards/E3179.htm for testing with masks? Would this be applicable?	36
Mickey, are there any studies on clothing disinfection or uses for public transportation with Far UVC? Thanks!	28
What types of N95 masks?	3
Would the measurement of the UVC require a special or very specific radiometer	43
Can ozone be used as an added benefit when decontaminating masks?	1
W hat log should each layer be inoculated to for testing? Has there been any guidelines given?	31
Is it true that longer wavelengths (e.g. 280 nm) produce less or no ozone?	38
Does anyone have any UV transmittance data on masks or mask materials (i.e. polypropylene, polyester, etc.)?	54
Can anyone comment on the use of 222 nm light from KrCl exciters? It should be at least, maybe more, effective than 254 nm from low pressure Hg lamps, and is likely to be safe for occupied spaces with respect to both skin and eye safety.	28
Does UVC negatively affect the electrostatic charge?	46
For 272nm, do we know anything about polychromatic UV (medium pressure) in the context of damaging the N95 mask?	48
Are there any known viruses that are not susceptible in 250-280 Nm UV range? How does the disinfection differ under 280 Nm vis a vis 253 Nm?	17
Do you agree that Hydrogen Peroxide if not in Vapor (e.g.: nebulize) is detrimental to N95 mask?	1
What is the maximum temperature N95 masks can withstand without degradation?	49
Are there resources that describe whether, for a low-pressure mercury bulb, the relative light intensity from the small higher-wavelength peaks tracks with the intensity at 254 nm? Do these ratios remain constant across different low-pressure mercury bulb models and during the lifetime of the bulb (with solarization, etc.)?	10
Can traditional mercury vapor lamps be used for disinfection/decontamination?	7

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In regards to measuring the dosage, does the device being used matter? Is there any approval for the device that needs to be looked for?	43
Has there been a definitive dosage delivery recommendation in mJ for hard surfaces for SARS-CoV-2?	18
Why are there no Far UVc 222 nm LED emitters?	29
John mentioned that large droplets are more important in human-to-human transmission than tiny droplets. Any explanations on this?	2
Would CDC labs be willing and able to determine the UV dose response curve for SARS Civ-2? Jim Bolton	19
As far as I understand, the penetration depths through the different layers of the mask was referring to a wavelength of 254nm. Would that differ for 230 or 265nm, which can be supplied by UV LEDs?	54
So, to summarize, if you could specify the irradiance and dose of a 254nm system that would be effective using the research we have now, what would you use in mW/cm² and mJ/ cm²?	3
How can LED´s can be used for N95 Treatment with their low UVC output? They would need much longer treatment time compared to electronic discharge lamps which would be ineffective for most applications	20
222nm exposure is allegedly less dangerous for human skin and corneal tissue. Do we know of LED's under developed emitting this wave-length?	28, 29
Does UVC 254 nm works for porous objects like fruits and vegetables?	8
Can you comment on UVA or 405 nm disinfection?	7
Has an inactivation dosage been established for aerosolized coronaviruses?	13
Any research on decontamination with a bleach/ethanol spray then a drying process? Will this degrade the integrity of the mask to a point of non-functional? Just as a comparison method to UV and hydrogen peroxide.	1
Thank you for this opportunity to learn from the experts. Would you please be able to further elaborate on the discrepancy between the recommended target doses for N95s presented on ECRI slide 5 (150-500 mJ/ cm²) and the doses recommended in the CDC guidance (>500 mJ/ cm², based upon peer-reviewed literature evidence for >3-log reduction on N95 material)? Is there evidence that N95 surface decontamination only is sufficient?	21
How does the CDC come up with the 3 Log reduction minimum decon level? Is there any QMRA work performed on this? Is 3 Log reduction really enough?	42
Would a combination of UVC and heat be more effective?	1
What is the benefit (if there is any) of using a UV-C LED at 280nm (output/lifetime)?	22
Somewhere we don't have any UV source except sunlight. Is it an effective disinfectant for N95 mask?	7

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why then is DOSE of 40 mJ/cm^2 necessary?	23
US Govt agencies testing 272 nm against covid19 virion right now	24
if the necessary dose for inactivation cannot be provided. Are there chances that we will promote a mutation of the virus?	25
Because I see the benefits of deploying UVC after air filters in air plenum of central air conditioning systems to kill germs, has the association taken parts in ASHRAE's Technical Committee 2.9?	6
In situation where UVC is used to kill germs suspended in moving air, would UVC with ozone emission a better choice as the kill range can go beyond the travel distance of UV photons.	1
In the process of ozone generation, has any work done to identify any non-ozone, reactive oxygen species, such as singlet oxygen, superoxide, etc.?	1

Response	Summarized Question Topics	Related Ques	IUVA's Response
1	Regarding questions on use and possible benefits of other forms of disinfection treatment for N95 masks and comparisons of other technologies to UVC (e.g., UVA, H_2O_2, ozone, forced air, heat, alcohol, etc.).	6, 39, 65, 74, 91, 94, 101, 102	According to IUVA's scope and charter, IUVA is entirely focused on the efficacy and benefits of UV technologies. Accordingly. we choose not to comment on other technologies' or products' efficacy or effects, whether individually or in combination with UV.
2	Regarding questions on COVID-19 transmission pathways, droplet sizes of interest, minimum safe distance calculations, etc.:	46, 57, 81	The authoritative source for guidance on these issues can be found in CDC's guidance on "Prevent Getting Sick" (https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/index.html), which is frequently updated to reflect the latest research findings on the COVID-19 situation. See also Response #'s 31 & 39.
3	Regarding questions on N95 respirators - the models, their availability, specific materials used and approximate dosage levels required to decontaminate them.	63, 84	A good resource for the types and models of N95 respirators and current thoughts on recommended dosage levels required for decontamination is CDC's guidance "Decontamination and Reuse of Filtering Facepiece Respirators" (https://www.cdc.gov/coronavirus/2019-ncov/hcp/ppe-strategy/decontamination-reuse-respirators.html); would specifically refer to Table 4 in that document. See also Response #5.
4	Regarding the availability and sources of N95 respirators:	22, 47	We suggest questions on the sources on N95 respirators, the acceptability of international masks and the risks of buying fake N95 masks are best referred to the FDA and CDC, using contact information provided on their respective COVID-19 websites. As to the relative availability and economics of new vs. decontaminated, that will vary as the number of new decontamination processes increases and the production rates of new masks grows to meet demand; any projections would be purely speculative and any driving decisions within the sole purview of the individual institutions involved.
5	UV has been suggested as a method for disinfecting surfaces, especially in hospitals. How does it compare with more traditional methods including various chemical sprays? Is there any experience to suggest typical irradiance levels and exposure times?	7	UV disinfection in the hospital is intended as a supplement to manual cleaning and disinfection processes. Manual cleaning and disinfection focus on wiping down high-touch and soiled surfaces with an approved wipe, and therefore does not disinfect every surface. UV disinfection may help reduce bioburden reservoirs. There is a large body of evidence showing the efficacy of UV disinfection, especially low-pressure mercury lamps, for inactivation of organisms on hospital surfaces. Most studies have been performed on nonporous, smooth surfaces, such as stainless steel or plastic. However, there is little high-quality, published literature linking UV to reductions in HAI rates. This is likely due in part to the many confounding variables, such as hand hygiene practices, amount and type of chemical cleaning performed, and the surfaces being cleaned.

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			Although irradiance varies dramatically by device, doses in the range of 10 to 100 mJ/ cm^2 have demonstrated at least 3-log reductions of different target organisms. Regarding the comparison of UV to alternative methods, such as hydrogen peroxide vapor, please refer back to Response #1.
6	Is UV disinfection effective for treatment of air, especially when used in HVAC systems? IS IUVA active in ASHRAE technical committees?	56, 59, 100	UV disinfection technology is available for air disinfection in public areas (e.g., upper-air UV device) and for use in HVAC systems. Upper-air UV devices are placed high in rooms, above the heads of occupants, to inactivate organisms in the air. They rely on air circulation to push "contaminated" air from the occupied space into the UV zone, and to return disinfected air to the occupied space. UV systems in HVAC may be used to limit bacterial and fungal growth on the coils themselves, or in conjunction with filters to inactivate organisms in the ducts, for transmission to occupied spaces. Regarding ASHRAE involvement, several senior IUVA members are actively involved in ASHRAE's technical committees, and often bring in additional IUVA resources to address specific issues. Just before the Covid-19 pandemic issues broke open, preliminary meetings have been held two ASHRAE technical committees about negotiating an MOU similar to the one between IUVA and IES, and the discussions were very favorable. These discussions are expected to resume in the near future.
7	What sources of UV light are effective for disinfection? Do UVA or 405 nm disinfect? When UV sources are unavailable, can sunlight be used?	44, 77, 88, 96	Low-pressure mercury lamps and UV sources at 254nm are well-supported by clinical literature. Other wavelengths (e.g., 222 & 405nm, and LEDs in the range of 260-280nm) have also shown efficacy. Sunlight includes light in the UVB (280-320nm) range, which has also shown some germicidal effects. However, reaching effective doses for N95 decontamination may be challenging. Some consumer-grade devices, including CPAP UV devices, may be effective. However, these devices rarely provide information regarding the wavelength and intensity of emitted light, and therefore the use of these devices is not scientifically supported.
8	Does UVC 254 nm work for porous objects like fruits and vegetables?	87	UVC has been used to disinfect fruits and vegetables successfully, for several years. Many good studies are available through the IUVA Web-site and the FDA web-site. For example: http://www.iuva.org/UV-Light-Technology-As-an-Emerging-Tool-For-Food-Safety
9	@ ECRI & Smith: Are there currently any UV "decontamination" devices available for clinicians in private practice, and not practicing in large institutional settings. Thank you. GREAT talk by all!	51	There are commercially available countertop UV disinfection devices that are designed to disinfect small items with smooth surfaces - like a cell phone. These devices are typically designed for short cycle times that deliver doses in the range of 30-50 mJ/cm^2 - lower than most recommendations for N95 decontamination. These devices may be suitable if the cycle time can be extended to provide a higher UV dose. ECRI has also seen an increase in availability of small UV chamber devices that are intended specifically for N95 decontamination. These devices are likely to provide a higher dose, but are new to market

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			and have not been tested extensively in a clinical setting. They are typically less expensive than large UV towers and may be more accessible to smaller practices as a result.
10	Are there resources that describe whether, for a low-pressure mercury bulb, the relative light intensity from the small higher-wavelength peaks tracks with the intensity at 254 nm? Do these ratios remain constant across different low-pressure mercury bulb models and during the lifetime of the bulb (with solarization, etc.)?	76	Our sources do not have any readily available data on whether or not the relative intensities of the wavelength peaks vary in proportion to one another. The assumption is that they do not track and each wavelength will need to be measured to get accurate irradiance for calculating dose attributable to each wavelength. Variation between wavelengths, especially of the longer wavelength peaks, might also depend upon bulb fabrication techniques, bulb coatings, etc., and may even depend on bulb operating temperature. One manufacturer confirms that the wavelength peaks degrade at different rates over the bulb's life for its various bulbs, and, regardless of lamp type, deprecation of output is more severe at 185nm vs 254nm.
11	Can you provide comments on specific UV devices or manufacturers?	53	The IUVA is an impartial organization does not comment or endorse specific products or manufacturers. For information on best practice, please see our guidance document: *http://www.iuva.org/Advice-selection/operation-of-equipment-for-the-UV-disinfection-of-air-and*
12	What is the origin of organism response plateau at high doses? Is this a real effect or measurement artifact?	30	The "tailing" behavior that may show up in dose-response data sets is often related to an approach to the limit of detection in the assay. However, there is also evidence that natural variability may result in a fraction of microbial population expressing resistance to environmental stresses, such as UV irradiation.
13	Do we know if there are any labs currently testing with UVC on N95 material with the CoV-2 inoculum? Has the inactivation dosage been established for aerosolized coronaviruses?	31, 89	At the time of publication, we were not aware of any, however, this is a rapidly evolving area that changes daily.
14	Is there a trend to use lamps over LEDs for masks?	33	Most systems appear to be based on conventional low-pressure Hg lamps, but alternative UV sources, such as UV LEDs or plasma (excimer) lamps, can also be used for these applications. There are advantages and disadvantages of each source type.
15	RE: the D90 of Covid-19. One participant stated the D90 of Covid-19 had been established.	37	This represents critically important information that the entire engineering community would benefit from. We encourage you to pursue publication of this information in the refereed literature.

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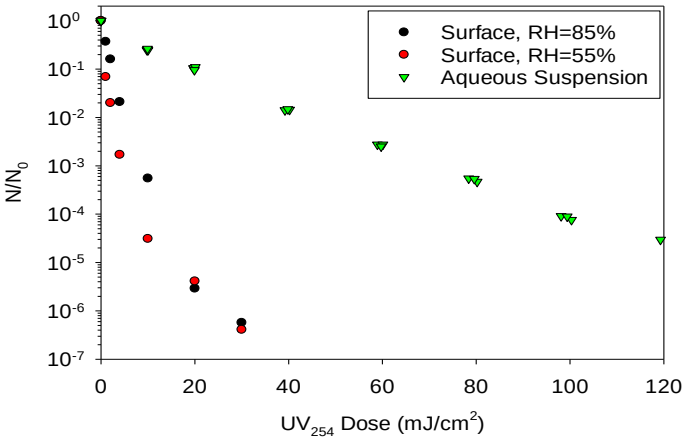
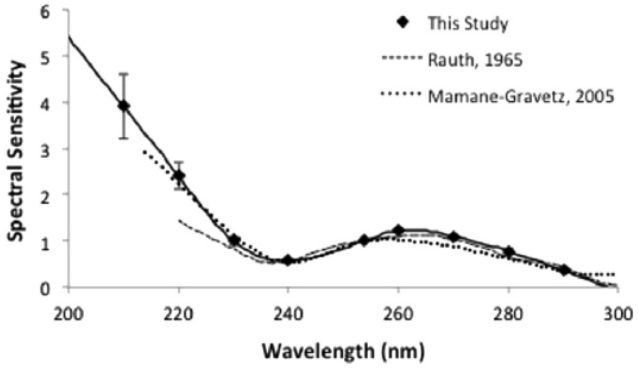
16	Is the dose required for surface disinfection the same dose required for water disinfection, or is there a different calculation for the two?	45	In general, Figure 1 (below) illustrates the UV254 dose-response behavior of coliphage MS2 on surfaces and in aqueous suspension. These data clearly indicate that MS2 is much more sensitive to UV254 exposure on a surface than when suspended in water. Similar trends have been reported for other microbes. It is likely that drying (desiccation) of the microbes on surfaces plays a role in increasing their sensitivity to UV254 exposure. It is also likely that similar trends will be observed with other viruses, such as SARS-CoV-2, and at UV wavelengths other than 254 nm. MS2 is a relevant virus to use for this comparison because like SARS-CoV-2, it is a single-stranded RNA (ssRNA) virus. However, it is important to recognize that SARS-CoV-2 is an enveloped ssRNA virus, whereas MS2 is a non-enveloped ssRNA virus. The viral envelope is thought to render viruses more susceptible to environmental stresses (such as UV exposure) than similar non-enveloped viruses. Therefore, it is likely that SARS-CoV-2 will be inactivated more rapidly by UV exposure than MS2.  **Figure 1. UV254 dose-response behavior for coliphage MS2 on surfaces and in aqueous suspension. Data for inactivation responses of surface-associated MS2 are from Tseng and Li (2007)6 and include relative humidity (RH) conditions that viruses were allowed to equilibrate with prior to UV exposure. The data for the aqueous suspension were provided by HDR/HydroQual.** 

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			Figure 2. Normalized action spectrum for coliphage MS2 (from Beck et al., 2015).7 Note that the convention with action spectra is to normalize against the measured kinetics of inactivation at 254 nm.
17	Are there any known viruses that are not susceptible in 250-280 nm UV range? How does the disinfection differ under 280 nm vis a vis 253 nm?	73	All viruses contain a nucleic acid (DNA or RNA) that is surrounded by a protein coat called a capsid. Some viruses are also enclosed in an envelope of proteins and fats. The most basic mechanism of microbial inactivation by UV exposure is photochemical damage to nucleic acids; this type of damage takes place at essentially all UV wavelengths less than about 320 nm. Below 240 nm, photochemical damage to proteins also becomes an important contributor to viral inactivation. Because of this, all viruses are susceptible to damage and inactivation by UV exposure, but some are more susceptible than others. From a mechanistic perspective, viral inactivation in the range of 250-280 nm is likely to be very similar. However, there will be differences in the kinetics (rate) of inactivation across this wavelength range, largely associated with changes in UV absorption by DNA or RNA, which in turn are governed by the structure and composition of these molecules. These trends are captured in a quantitative sense by the so-called "action spectrum" of a given microorganism. Figure 2 illustrates the action spectrum for MS2. As with most microbes, there is a local maximum of the rate of inactivation at a wavelength of about 265 nm, corresponding to a local maximum in UV absorbance by the microbe's nucleic acid. For wavelengths less than about 240 nm, viral inactivation tends to be rapid as a result of damage to proteins in the viral capsid. Note that no action spectrum has been reported for SARS-CoV-2 to date.
18	Has there been a definitive dosage delivery recommendation in mJ for hard surfaces for SARS-CoV-2?	79	To date, the responses of SARS-CoV-2 to UV exposure have not been reported in the refereed literature on or in any medium. However, this is a rapidly evolving area that changes daily
19	Would CDC labs be willing and able to determine the UV dose response curve for SARS-CoV-2?	82	It is not known if CDC plans to conduct this experiment.
20	How can LED´s can be used for N95 Treatment with their low UVC output? They would need much longer treatment time compared to electronic discharge lamps which would be ineffective for most applications.	85	UV LEDs tend to have relatively low output power as compared with conventional LP Hg lamps. However, this aspect of LEDs can be overcome through the use of multiple LEDs, such as in flat-panel displays. LEDs may also present an advantage by allowing reduction of the distance between the N95 and the radiation source. For example, LEDs may not be realistic at a distance of a meter or so, but may be effective when placed within a few cm of the mask.
21	Please be able to further elaborate on the discrepancy between the recommended target doses for N95s presented on ECRI slide 5 (≥150-500 mJ/cm^2) and the doses	8, 92	ECRI has calculated a minimum recommended dose based on: 1) existing data on coronaviruses, 2) the properties of N95 FFRs and commercially available UV devices, and 3) previous studies and CDC guidelines for limited reuse that have focused on the

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	recommended in the CDC guidance (>500 mJ/cm^2, based upon peer-reviewed literature evidence for >3-log reduction on N95 material)? Is there evidence that N95 surface decontamination only is sufficient? What is the irradiance in mw/cm^2?		risk of contact transmission. In contrast, the CDC does not make specific dose recommendations, but provides a summary of data on antimicrobial efficacy. The cited studies have shown >3-log efficacy against other viruses on N95s by applying doses greater than 500 mJ/cm^2. ECRI is not aware of studies that have applied doses in the range of 150-500 mJ/cm^2 on N95s; therefore, ECRI's dose recommendation is intended to supplement, not replace, existing CDC guidance on limited reuse for single-users. (Note: mJ/cm^2 = (mW*s)/cm^2) The guidance provided by FDA and CDC does not explicitly recommend decontamination of N95s prior to reuse, or what level of inactivation of viruses within the internal structure of an N95 mask is required. The CDC's guidance on limited reuse of N95 masks focuses on the risk of contact transmission, but much is still unknown about SARS-CoV-2 and the risk of infection associated with reuse of N95 masks. More generally, good disinfection practices focus on removing or inactivating as much bioburden as possible, and inactivating viruses throughout all layers of the mask would be consistent with this goal.
22	What is the benefit (if there is any) of using a UV-C LED at 280 nm (output/lifetime)?	95	UV LEDs offer potential benefits of being able to conform to essentially any shape, offering the opportunity to select output wavelength range (by selection of LED material composition), by providing essentially instant on/off functionality, and by being mercury-free. The expected lifetimes of LEDs and low-pressure mercury lamps are comparable – typically on the order of thousands of hours.
23	Why then is dose of 40 mJ/cm^2 necessary?	97	It is not clear what this question is alluding to. A nominal dose of 40 mJ/cm^2 is a common standard applied for drinking water disinfection.
24	US Govt agencies testing 272 nm against COVID-19 virion right now.	98	That is great to hear. We hope that these data will be published in the refereed literature soon, along with similar data at other wavelengths.
25	If the necessary dose for inactivation cannot be provided, are there chances that we will promote a mutation of the virus?	99	It is well-established that UV radiation causes damage to the genome, and in fact it is this process that we depend on to accomplish disinfection. The specific nature of these mutations has been explored in great detail and is known to be responsible for inactivation of viruses and other microbial pathogens. However, there is no evidence to indicate that UV exposure promotes mutations that can be carried to subsequent generations of pathogens.
26	How about efficacy of far-UV 222nm, or combination of 222nm & 254nm? Thanks!	35	Far UV-C (200 - 225 nm) is expected to show efficacy against a wide range of microorganisms, as is observed for conventional germicidal UV (250 – 280 nm range, principally 254 nm). Photochemical theory supports the ability of far UV-C to damage genetic material (DNA/RNA) and proteins in a manner similar to conventional germicidal UV, and numerous studies have

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			demonstrated inactivation of microorganisms by far UV-C sources. There is sufficient evidence to state that far UV-C irradiation is an effective disinfectant, though limited data exists to determine the efficiency against a specific microbial target.
27	Has anyone used a 187nm wavelength lamp in an enclosed chamber for mask decontamination or has all the testing been done with 254nm only?	28	We are not aware of any studies using 187 nm lamps for N95 respirator decontamination. Two additional considerations are required at this wavelength, being: the generation of ozone from oxygen, which is a known issue for this wavelength; and the potential for damage to the materials of the mask, since the more energetic photons in this range cannot be considered equivalent to those at 254 nm, which are known to not cause such damage.
28	There are many reports that Far UV 222 nm light is more effective at lower doses than 254nm and safer to use when people are present. Does anyone on this webinar have info on 222 nm Far UVC? Any studies on clothing disinfection or uses for public transportation with Far UVC? Any comment on the use of 222 nm light from KrCl excimers? What about 222nm safety?	25, 62, 69, 86	Media and public interest in far UV-C radiation (200 – 225 nm) has dramatically increased during the COVID-19 pandemic, though the technology has been studied within the industry for many decades. The most common sources in this wavelength range are KrCl* excimer lamps which operate by a plasma discharge mechanism and show a major peak at 222 nm. It is important to note that spectral impurities of KrCl excimer lamps, if not properly managed, can result in broadband emission from these lamps across most of the UV-C range, masking the results attributable to 222nm, alone. Far UV-C is expected to show efficacy against a wide range of microorganisms, as is observed for conventional germicidal UV (250 – 280 nm range, principally 254 nm). Photochemical theory supports the ability of far UV-C to damage genetic material (DNA/RNA) and proteins in a manner similar to conventional germicidal UV, and numerous studies have demonstrated inactivation of microorganisms by far UV-C sources. There is sufficient evidence to state that far UV-C irradiation is an effective disinfectant, though limited data exists to determine the efficiency against a specific microbial target. With regards to specific application of far UV-C to the decontamination of N95 respirators, it would be reasonable to assume anti-microbial efficacy given sufficient exposure, though specific effects of this shorter wavelength radiation on the materials of the mask would need to be studied. Good evidence suggests that conventional germicidal UV does not damage mask materials or functionality, though far UV-C would require specific study since photons in this range are of substantially higher energy and may cause unintended chemical reactions or degradation. As with conventional germicidal UV, the ability of far UV-C to inactivate microorganisms on textiles such as clothing will depend heavily on the fabric, its density, any dyes or pigments present, and its orientation to the source. When UV radiation is obstructed, shadowed regions can limit overall disinfection efficacy. This can be seen in analogue to the discussion of N95 respirator decontamination, where recommended UV exposures

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			(~1000 mJ/cm^2) are an order of magnitude or more above requirements for conventional surface disinfection to compensate for shadowing. Claims of skin and eye safety of far UV-C are based on a biophysical concept that these higher-energy photons are absorbed in the outer dead skin or tear layer, therefore not reaching the live cells underneath and not causing damage. Several studies have irradiated mouse tissue and found no conventional indicators of skin damage; however, no clinical studies have demonstrated the safety of this technology for human cells. One study of human exposure has been published, in which conventional skin damage was observed; however, the study noted long-wavelength spectral impurity of the 'far UV-C source' up to 260 nm, which may have contributed to this effect. Please see also the recent IUVA White Paper – "Far UV-C in the 200 – 225 nm range, and its potential for disinfection applications" *(https://iuva.org/resources/covid-19/Far%20UV-C%20in%20the%20200%20_%20225%20nm%20range,%20and%20its%20potential%20for%20disinfection%20applications.pdf)*
29	Why are there no Far UVC 222nm LED emitters? Are LED's under developed emitting this wave-length?	80, 86	UV LEDs are semiconductor devices in which the emission wavelength can be tuned by varying the chemical composition of the 'active layer', a compound of aluminum, gallium, and nitrogen; a lower concentration of aluminum in this layer will lead to longer wavelengths (blue, UVA), whereas a higher concentration leads to LEDs which emit shorter wavelengths (UV-C). LEDs based on AlGaN have been demonstrated with peak emission as short as 210 nm, though only within a single laboratory; far UV-C LEDs at longer wavelengths (e.g. 222 – 227 nm) have been manufactured in a small number of laboratories. Far UV-C LEDs are a long way from commercialization, with output powers in the micro-watt range and electrical efficiencies of just a fraction of a percent. Experience from longer-wavelength UV-C LEDs gives confidence that these devices will improve and may be useful tools of the future, though it is certain that they will not find use in disinfection applications during COVID-19.
30	Does the FDA & CDC accept testing results from outside accredited S3 independent laboratories?	11	In general, any federal submissions require data collection under Good Laboratory Practices (GLP). There is no accreditation for GLP, but, rather, a series of criteria covering data collection, documentation, and oversight. It is assumed that S3 indicates biosafety level 3 (BSL3). Testing against SARS CoV-2 requires BSL3 facilities. There are surrogates, however, such as human coronaviruses 229E and OC43, that may be acceptable and can be tested in BSL2 facilities.
31	In testing the masks, would droplet application significantly affect the masks which we want to test, say relative to aerosolizing application? What log should each layer be inoculated to for testing? Has there been any guidelines given?	16, 66	It is assumed that testing against droplets would differ from aerosols. However, it is unknown at this time, how UV dose requirements would differ between the two different inoculate. Inoculation of the mask should occur on the outside of the mask. However, there is very little guidance from the FDA or other federal agencies for how masks should be inoculated. The

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			current guidance requires a 3-log virus kill and a 6-log spore former kill. Therefore, you would need to inoculate with at least 3 to 4-log virus and 6 to 7-log spores.
32	Also, literature shows usage of MS2 phage in mask decon, where we saw 1-2 mJ/cm^2 for 3log reduction. What is the most appropriate surrogate for the current coved testing, given that MS2 seems more resistant to UV compared to Covid, and testing with it could be overkill?	21	There are two common surrogates for SARS CoV-2, human coronaviruses 229E and OC43. There are other enveloped RNA viruses, such as H1N1 Influenza A, that may be acceptable surrogates. Another consideration is 'soiling' (i.e., prepping the inoculate to more closely mimic actual field conditions). There are several choices, to include artificial human saliva, porcine saliva, bovine saliva, & sterilized fecal matter. Standardizing inoculate 'soiling' is needed for consistent test results.
33	How do you test the effectiveness of UVC in cleaning N95? What is the UVC irradiance and dose?	23	At this point, the most appropriate endpoint measurement for UVC decontamination of N95s is detection of viral activity following irradiation of inoculated N95 masks. For guidance on irradiance & dose, please refer back to Response #'s 3 & 21, above.
34	Should microbial testing for device effectiveness be limited to only SARS type viruses? Should the testing not expand to other microbes in a healthcare facility, which might require a higher dosage?	36	The FDA Emergency Use Authorization for N95 disinfection requires efficacy against a viral load as well as efficacy against relevant bacterial/fungal pathogens. There appears to be some range of bacteria/fungi they will accept. As the focus is on Coved-19 Pandemic, there has not been efforts to include other risk factors, so far as this would complicate response to this emergency which is driving the current EUA process.
35	Can you comment on the limiting factors contributing to why a UVGI N95 reprocessing technology has not yet received an FDA EUA?	42	The FDA EUA guidance indicates a 6-log kill on a spore-former. It is difficult for UVC devices to achieve this level of kill within dosage limits (see studies on UVC degradation of masks). Further, the outer layers of N95 masks inhibit the path of light through the mask. There are also testing issues around how best to inoculate the masks to insure the is a sufficient pathogen load to assess and measure a 6-log kill. This webinar will result in feedback and suggestions to the FDA on possible improvements to the EUA process as applied to UV technologies.
36	What about the standard https://www.astm.org/Standards/E3179.htm for testing with masks? Would this be applicable?	61	ASTM E3179 tests the effectiveness of UV to kill microorganisms on fabrics containing an organic soil. It is an acceptable start point for testing with N95 masks. However, efforts need to be made to account for the multiple layers of a N95 mask.
37	UVC lights are known to generate ozone, is this a problem?	5	The generation of ozone will depend on the type of quartz tubing used to make the lamp. The quartz tubing can be "doped" to block or greatly attenuate the level of ozone generated by the lamp. In most cases the amount of ozone generated by the doped lamps is nominal and will be destroyed by the 253.7 energy or will dissipate rather quickly when exposed to the UVC energy and the ambient air. The lamps look identical and care should be taken to confirm with the lamp / product manufacturer to confirm ozone generation.

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38	Is it true that longer wavelengths (e.g. 280 nm) produce less or no ozone?	67	Ozone is generated in the 100-240nm range the peak line for ozone generation is 185nm. That being said, most low-pressure mercury vapor and medium pressure mercury vapor UVC sources are not monochromatic so care should be taken to determine the spectral output of the source doesn't inadvertently emit ozone-producing wavelengths. Many UVC equipment manufacturers use quartz that is designed to block the shorter wavelengths <240nm. Also, the energy at longer wavelengths will actually break the bond of the third oxygen atom that creates ozone. (See Response #37, above)
39	What is the UVT through each droplet? Is it modelled after water with 90% UVT or virion embedded in 1% serum?	49	Some labs have been using artificial saliva with a UVA of 9.4 cm-1, contaminating masks with droplets of 1 uL (d=1241um). The loss of UV light across this path length is about 97%. However, the droplets are dried and the interference for salts and proteins (e.g., using mucin) are probably not well described by the above calculation. Salts do not absorb at 254nm when dissolved but will shield light once crystalized.
40	Re: getting the inoculum to stay on the mask material, sometimes requiring 7 or 8 or 9 log applied to the masks in order to prove 6 log reduction. It is a challenge getting that amount applied before the UVC treatment.	50	It is difficult to contaminate the mask with large droplets. One lab has been using 1-2 uL for with repeated application to get a total volume of 10 uL in a contaminated region of 1 cm^2. With spores and phages, it is not too difficult to get an initial load of 6 log in the contaminated region. With bacteria, they had to centrifuge the stock suspension to increase the titer. This step raises the risk of having bacterial aggregates in the stock (even if fully vortexed prior to application). However, it was the only way to get around 9 log/mL in the stock used to inoculate the masks.
41	Re: the protocol baseline for challenging 254nm or 272 nm of inoculate on glass slide.	55	One lab did tests using spores dried on microscopic slides inserted under the first layer of N95 mask. As glass cover slips don't let UV pass through, it is a simple approach to understand the impact of light is coming from one direction. However, this option does not account for the interaction of organisms with the N95 materials.
42	How does the CDC come up with the 3 Log reduction minimum decon level? Is there any QMRA work performed on this? Is 3 Log reduction really enough?	93	Our SME's are not aware of a QMRA performed on a N95 mask treatment. It is believed that the FDA just cut in half the requirement for sterilization (6 log). Given that N95 masks only do about 2 log reduction of viruses by filtration, it also makes sense that achieving a disinfection level above the filtration performance of a mask will probably lead to the risk being controlled by filtration performance rather than UV disinfection performance.
43	What are your recommendations to measure UV dose correctly? Would the measurement of the UVC require a special or very specific radiometer? In regards to measuring the dosage, does the device being used matter? Is there any approval for the device that needs to be looked for?	27, 64, 78	Measuring UV dose correctly requires an energy meter that has been calibrated by a company that is traceable to the SI Unit through a national metrology institute. The key is that the calibration geometry (where the UV is irradiating the meter in a collimated fashion or diffusely from all directions) has to be similar to the application geometry. Measuring diffuse UV with an energy meter calibrated in a collimated geometry has shown to give errors over 200%.

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44	Recommendations on chemical dosimeters? Accurate dosimetry seems to be an issue, hearing from NIST that measurements can vary by up to 50% for different calibrated systems. How good are the chemical dosimeters and how do we know that? Do we have any chemical dosimeters to ascertain dose at this level of irradiance?	34, 38, 41	A few chemical dosimeters are commercially available. Peer-reviewed references on the fundamental chemistry show these can be accurate. One of the advantages of the chemical dosimeters is the chemical reaction is much less sensitive to geometry compared to certain radiometers. A couple disadvantages are not an immediate response, one-time use, and requires additional instrumentation to measure the color change accurately. Third-party researchers are validating the commercially available forms of these chemical dosimeters. Initial measurements are reassuring and will be published in peer-review literature soon.
45	Is there a national standard for measurement of UVGI?	40	Currently there are no accredited national standard test methods for UVGI. The IUVA is working with the Illumination Engineering Society on several test methods that will cover different technologies that produce UVGI and different applications using UVGI. There is one international standard for linear low-pressure mercury tubes which was published a couple months ago, ISO 15727:2020 UV-C devices — Measurement of the output of a UV-C lamp.
46	What impact does the UV light have on the electrostatic fibers? Do UV Hg lamps ionize the air such that it could mitigate the electrostatic charges in the mask? Does UVC negatively affect the electrostatic charge?	14, 17/18, 24, 70	UV has no known impact on the electrostatic properties of N95 masks, even after repeated exposures.
47	Do all N95s have the hydrophobic outside layer or only surgical FDA cleared N95s?	19	FDA surgically rated N95 masks are required to have a hydrophobic layer, for the safety of Healthcare Providers "who need protection from both airborne and fluid hazards, such as splashes or sprays" (https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/index.html). Other types of N95 masks may have layers that provide some degree of hydrophobic protection, but it is not a Federal requirement.
48	Do we know anything about polychromatic UV (medium pressure) in the context of damaging the N95 mask?	71/72	There is no indication that multiple UV wavelengths used at the same time causes damage to N95 masks. However, high temperatures (75°C or higher) and/or the presence of ozone, often associated with MP-Hg lamps, would risk damage to the mask.
49	What is the maximum temperature N95 masks can withstand without degradation?	75	Found no Federal guidance on maximum temperatures permitted, however CDC recommends treatments (e.g., mild steam) at no more than 60°C to prevent degradation. One manufacturer recommends not exceeding 75°C. (https://multimedia.3m.com/mws/media/1824869O/decontamination-methods-for-3m-filtering-facepiece-respirators-technical-bulletin.pdf).
50	Applying high UV doses, wouldn't that cause the temperature to rise too much?	29	Higher UV doses are not known to cause any significant increases in mask temperatures.

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51	The shadowing effect is a concern because most people don't understand the concept. Can you help everyone understand the point of concern? Is there a recommendation on how to handle shadowing? Are there practical solutions to mitigate this risk in a real-world setting? And would increasing irradiance improve the disinfection through mask layers?	9, 43, 54	Folds, corners, and overlaps, internally and externally, literally generate shadows when UV light is applied. Since UV can't disable what it can't light up, these shadows degrade UV performance. The remedy? Either eliminate the shadow causing anomalies or apply a higher dosage to the whole unit. How much more is often a matter of opinion – that's why some testing labs recommend 150mJ/cm^2, some recommend 500 mJ/cm^2, and some recommend 1,500-2,000 mJ/cm^2, just to be safe. No clear standard exists, costing time, money and reducing N95 lifespans
52	Has anyone looked at highly diffuse reflective media in disinfection chambers to improve the disinfection of these masks?	26	Highly diffuse reflective media would have the effect of scattering the UV in more directions, potentially covering more area. However, this scattering weakens the UV energy being delivered because 1) no media is 100% reflective, meaning some of the energy is absorbed into the reflective surface; and 2) the further the UV light travels, the more quickly it degrades (as described in the "inverse square law" in physics). Any UV light bounced off of reflective media has to travel from the source to the reflecting surface and then down to the target. If that distance is twice the direct distance to the target, the dosage delivered in at most 1/4th the original strength. Highly diffuse media, with its scattering effects increase the distance traveled and the angle of incidence, just due to its basic nature, significantly reducing the UV dose at point of delivery.
53	Can forced air supplied from the face-side be used in combination with UV, simultaneously or sequentially, to assist in dislodging/expelling droplets from the internal fibers?	60	When analyzing the potential of reaerosolization of internally embedded contamination), CDC/NIOSH has found that "*more than ~99.8% have remained trapped on the respirator after handling or following simulated cough or sneeze.*" [CDC/NIOSH – "Recommended Guidance for Extended Use and Limited Reuse of N95 Filtering Facepiece Respirators in Healthcare Settings"]. Also please see Response #1.
54	Does anyone have any UV transmittance data on masks or mask materials (i.e. polypropylene, polyester, etc.)? Would increasing irradiance improve the disinfection through mask layers? [Also], the penetration depths through the different layers of the mask was referring to a wavelength of 254nm. Would that differ for 230 or 265nm, which can be supplied by UV LEDs?	10, 68, 83	The presenters know of no repository of UV transmission data on N95 mask layers; the only sources known are the individual studies done on specific masks and materials in particular applications. As for the differences in penetration depth between the various wavelengths, they all travel and penetrate in accordance with the inverse square law, mentioned before. The main difference would be in how much they are absorbed by the various materials in the mask, as each material has its own absorption spectrum, and different wavelengths get absorbed at different rates. As these wavelengths are not radically different, would not expect their absorption rates to be radically different, either. Regardless of wavelength, increasing irradiance always increases the amount of flux delivered to the various mask layers, improving the expected levels of disinfection.
56	Where can copies of the slides and related materials be found?	1, 3, 12	Copies of the webinar slides, a video of the webinar as presented, and related material can be found on the IUVA website at (*https://iuva.org/Expert-Perspectives-on-UV-as-a-Tool-for-N95-Decontamination-Webinar*)

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57	Does ECRI have recommendations on determining when a device no longer delivers the target dose and lamps have to be replaced?	48	Although a few devices measure lamp output and alert facilities when lamps need to be replaced, many currently available devices provide no indication when maintenance or lamp replacement is required. Device manufacturers commonly make statements about expected life of UVC lamps (typically several thousand hours) but healthcare facilities may find it difficult to track total usage hours. Further, ECRI has found that UV devices are not closely managed by engineering departments at many healthcare facilities, and that inspection and preventive maintenance may not be performed regularly. Facilities may consider pre-emptively replacing lamps at time-based intervals (e.g., annually, or every two years) based on expected life and estimated use; alternatively, they can purchase a service contract that will leave maintenance in the device manufacturer's hands. A third option would be to consider lamp output measurements, but measurement sensors can be expensive to purchase and maintain. Color-changing, card-based dosimeters may be a good option to confirm basic device operation and effectiveness, but may not provide the measurement resolution required to identify reduced lamp output that indicates lamps are approaching end of life.