Considering UV Light Exposures During Product Development

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Theme

- Because of our Broad knowledge of safety hazards, physical and chemical, CIHs often work as part of diverse teams.
- This was one of those projects

Agenda

- Equipment
- Project Description
- Team
- UV Hazard
- Recommended controls

Equipment - CSI – D+

- Handheld Multispectral Fluorescence Imaging System
- Contamination inspection is a need for food distributors and others who handle food.
- A tool that can rapidly detect, disinfect, and document invisible organic residues and biofilms which may host pathogens was being developed

CSI – D+

- Detects contaminants and respiratory droplets
- Spot disinfects in 2-5 seconds
- Documents inspection and sanitization
- AI Software records images
- Portable handheld
- Integrated UVC sanitization light
- Color-coded contaminant interface
- Not intended to disinfect large surface or be the primary means of disinfection

Method of Detection and Sanitation

- For the detection of organic residues wavelengths ultraviolet C (UVC) at 275 nm and violet at 405 nm
- The 275 nm - disinfect pathogens commonly found within the contaminated residues.
- Efficacy testing was conducted for Aspergillus fumigatus, Streptococcus pneumoniae, and the influenza A virus with deactivation (> 99.99%) in under ten seconds.

Method of Detection and Sanitation

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Project Description

Safety Spec needed guidance:

- Hazard information
- Energy level guidelines and standards applicable to operators
- Labeling and signage
- Draft safety guidance
- Types of personal protective equipment (PPE) needed.

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Team

- Product developer
- Marketing team
- University team
- Yorke CIH
- Engineering Physicist

CSI – D+ Team

- Safety Spec Team - develop and commercialize optical sensing technology for surface hygiene and food quality testing
  - Fartesh Vasefi – Chief Technology Officer
  - Nicholas Mackinnon - Director of Clinical Research
- Dr. Gregory Bearman, Ph.D. –Principal
  - ANE Image
  - Hyperspectral imaging expert, developed applications to biology, medicine and agriculture

SafetySpect

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CSI – D+ Team

- Yorke Engineering
  - Jim Hutchinson – Engineering Physicist
  - Jaime Steedman-Lyde – Certified Industrial Hygienist
- Biomedical Engineering Program, University of North Dakota
  - Mitchell Sueker M.S.
  - Kristen Stromsodt
  - Hamed Taherigorji
  - Bo Liang

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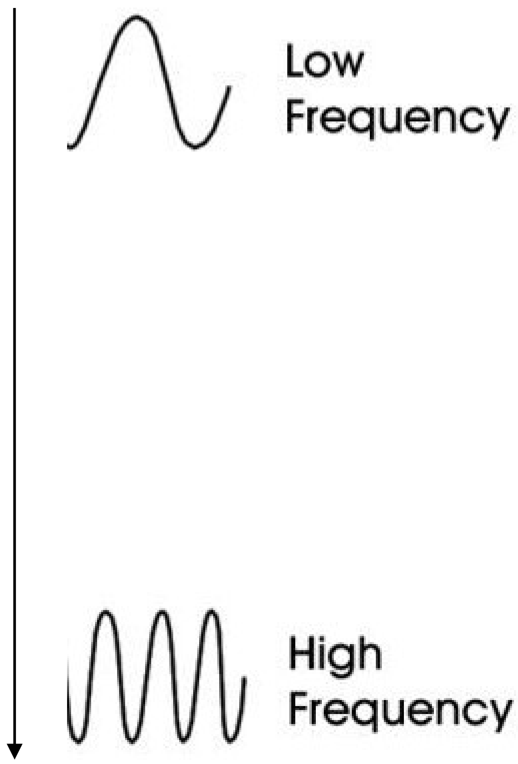
Non-Ionizing Radiation

- Extremely low frequency (ELF)
- Radio frequencies
- Microwave frequencies
- Lasers (IR to UVC)
- Infrared
- Visible spectrum
- Ultraviolet



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Hierarchy of Potential Hazard Concern

- Lasers
- Ultraviolet (UV)
- Radiofrequency (RF)/microwave
- Electric and magnetic fields (frequencies 30 kHz and below)
- Static fields (electric and magnetic)

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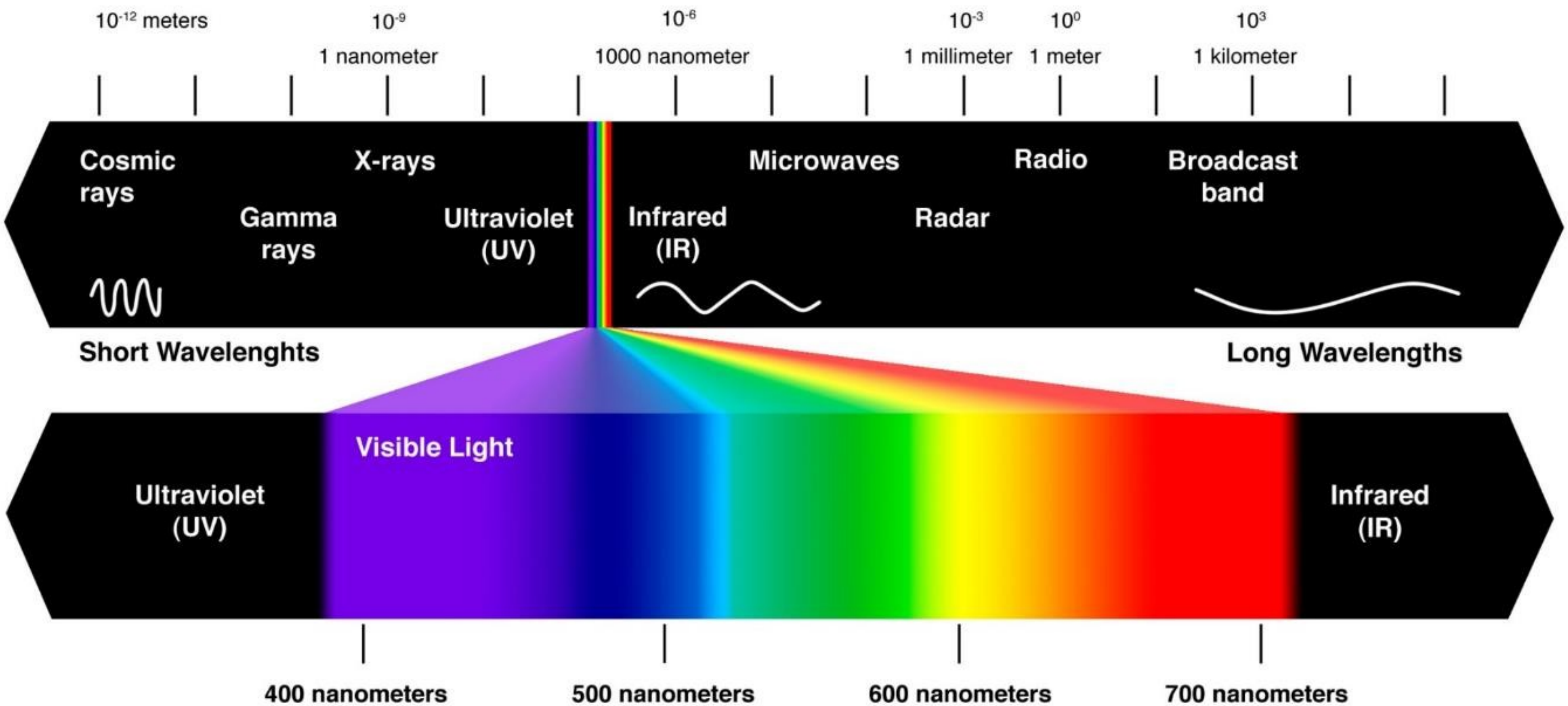

10-12 meters
10-9
1 nanometer
10-6
1000 nanometer
10-3
1 millimeter
10^0
1 meter
10^3
1 kilometer
Cosmic rays
Gamma rays
X-rays
Ultraviolet (UV)
Infrared (IR)
Microwaves
Radar
Radio
Broadcast band
Short Wavelenghts
Long Wavelengths
Visible Light
Ultraviolet (UV)
Infrared (IR)
400 nanometers
500 nanometers
600 nanometers
700 nanometers

Non-Ionizing Radiation

- Visible spectrum at wavelengths of 400 to 750 nm
  - ROYGBIV (red, orange, yellow, green, blue, indigo, violet)
  - Possibility of retinal injury from 400-500 nm (blue) frequencies – Not conclusive

Non-Ionizing Radiation

- Ultraviolet radiation: 180-400 nm
  - Bridge between non-ionizing and ionizing radiation
  - Three regions:
    - UV-A: 315-400nm
    - UV-B: 280-315nm
    - UV-C: less than 280nm

Ultraviolet Radiation

- Ultraviolet A (UVA) – longer wavelength
  - Associated with skin aging
  - Penetrate more deeply that UVB
  - Penetrates glass
- Ultraviolet B (UVB) – shorter wavelength
  - Associated with skin burning
  - Damages outermost skin
  - Does not penetrate glass

Ultraviolet Radiation

UV Band	Wavelength	Primary Visual Hazard	Other Visual Hazards	Other Hazards
UV-A	315 nm – 400 nm	Cataracts		Premature Skin Aging, Skin Cancer, Retinal Burns
UV-B	280 nm – 315 nm	Corneal Injuries	Cataracts, Photokeratitis	Premature Skin Aging, Erythema, Skin Cancer
UV-C	200 nm – 280 nm	Corneal Injuries	Photokeratitis	Premature Skin Aging, Erythema, Skin Cancer

Ultraviolet Radiation

- UVA, UVB and UVC bands
  - Acute exposure symptoms such as erythema (reddening of the skin) typically do not occur until 4 to 24 hours after exposure
  - chronic symptoms such as skin cancer do not appear until years later
  - Produce biologic effects on the skin and the eyes

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Occupational Exposure Limits for UV

- Cal/OSHA and Fed/OSHA do not have - General Duty Clause
- ACGIH – TLV - Almost all healthy workers may be repeatedly exposed without the occurrence of acute health effects
  - Accepted as the exposure “standard” in the U.S., Canada, and most of Europe.
  - Recommended by the WHO
  - NIOSH - Has recommended an OEL based on the TLVs

World Health Organization

TLV for UV – 315nm to 400 nm

UV Region from 315 nm to 400 nm

- Total irradiance incident shall not exceed 1.0 milli-Watt per square centimeter (mW/cm2) for more than 1,000 seconds (about 17 minutes),
- For exposure times of 1,000 seconds or less, the total radiant energy shall not exceed 1,000 Joules per cm^2 (J/cm^2).
- Note : 1 Watt is one Joule/sec

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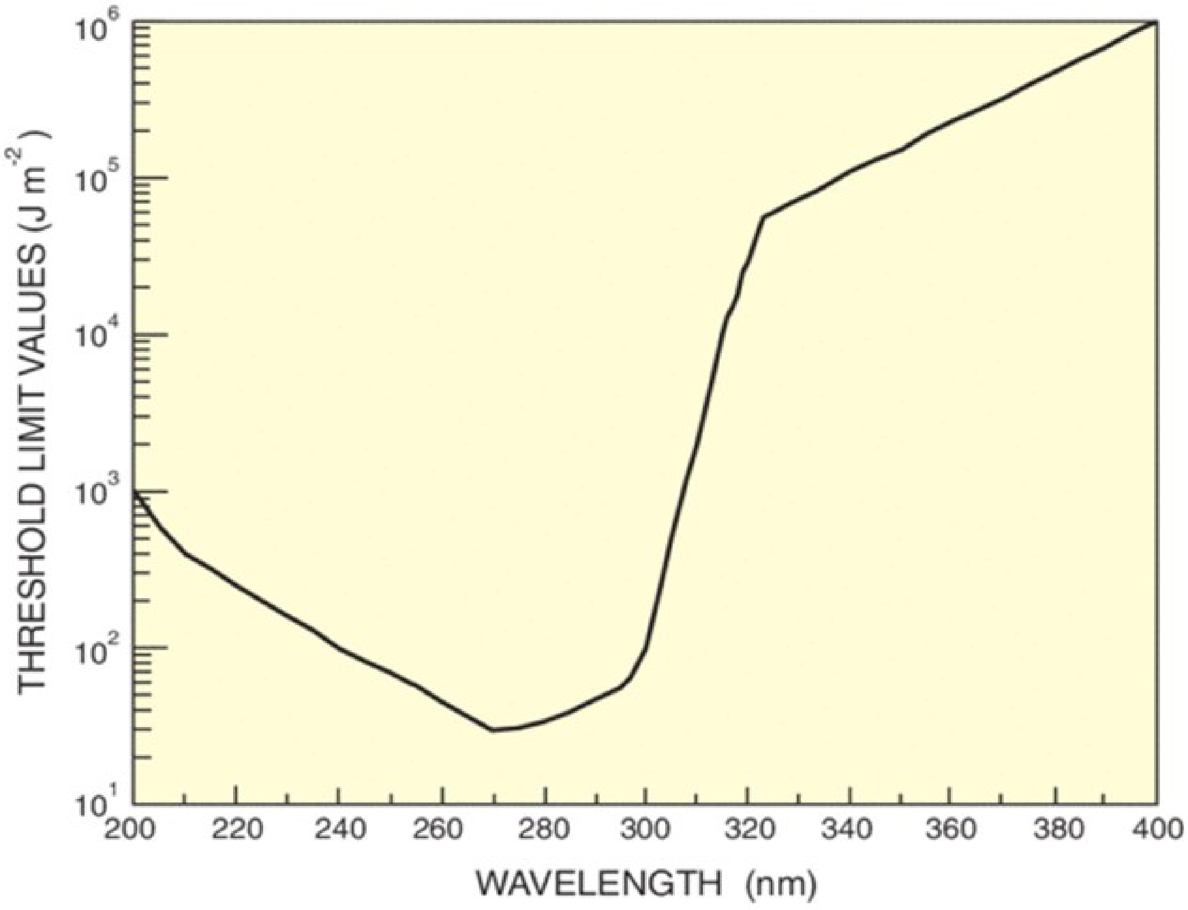
TLV for UV – 200 nm to 315 nm

- For the UV region of 200 nm to 315 nm
  - the total radiant energy shall not exceed 0.003 J/cm^2.
- The relationship between maximum allowable **exposure time** (t_{max}) in seconds, and effective irradiance (E_{eff}) is:

TLV for UV

- Broad band sources are weighted to determine the effective irradiance compared with the spectral effectiveness curve at 270 nm

TLV for UV



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Gathering Data for Comparison

- Effective irradiance measurements with radiometer
  - UVA+: 315 nm to 400 nm
  - UVBB: 230 nm to 400 nm
- Measurements were made to determine the effective irradiance at multiple distances and angles of incidence using the arrangement

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Data Collection

- Provided by University of Nebraska
- Illumination level data
- Intensity mapped from several angles
- Reflected power from a variety of substances and distances.

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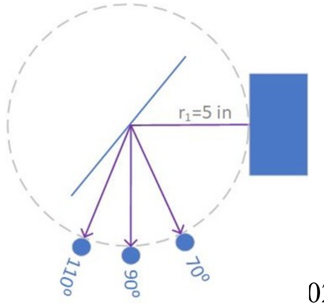
Collected Data - Irradiance

- Measured at Fixed 90º Angle of Incidence with UVBB and UVA+ Sensors at Various Distances from the Source
- Measured at Varying Angles of Incidence with UVBB and UVA+ Sensors at Fixed Distances from the Source
- Measured at Varying Angles of Reflectance with UVBB and UVA+ Sensors at Fixed Distances from the Source
- Irradiance Measured at Varying Angles of Reflectance with UVBB and UVA+ Sensors with different materials at Fixed Distances from the Source



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Example Data – At varied angles

Angle of Incidence (degrees)	UVBB Effective Irradiance, Eeff Measurement (mW/cm²)		UVA+ Effective Irradiance, Eeff Measurement (mW/cm²)	
	5 in	10 in	5 in	10 in
-30	*	0.005	*	0.175
-20	0.005	0.006	0.064	0.166
-10	0.004	0.003	0.081	0.159
0	0.006	0.002	0.053	0.146
10	0.01	0.007	0.148	0.29
20	0.058	0.003	0.724	0.252
30	0.784	0.004	0.996	0.161
40	1.252	0.013	2.469	0.419
50	2.432	0.184	5.748	1.464
60	3.804	0.931	12.628	5.059
70	5.178	1.853	19.891	10.167
80	5.86	2.62	27.594	13.758
90	6.353	3.104	35.444	14.362
100	**5.924**	**2.428**	**36.95**	**13.777**

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Collected Data

- The highest irradiance in the UV-B/UV-C range was 6.731 mW/cm2,
  - Directly in front of and 5 inches away from the source, which is the closest distance at which measurements were taken.
  - At this irradiance level, the ACGIH TLV data in Table 2 indicate that the maximum unprotected exposure time is only about 0.5 seconds

Collected Data

- the UVC energy density that is delivered by the CSI-D device to the surface, ranging between 6–33 mJ/cm2
- Approximately 10 feet would be needed to stay under the TLV for 8 hours.
- Not possible for an operator

Calculated Safe Distances

The minimum safe distance from the source at which no UV protection is needed can be approximated:

- Where x = Safe distance in inches from the source at which the TLV is not exceeded;
- E_{eff} = Effective irradiance at the safe distance; i.e., the TLV);

Calculated Safe Distances

Exposure Duration	ACGIH -Recommended Maximum Effective Irradiance, E_{eff} (mW/cm^2)	Minimum Safe Distance (ft)
8 hours	0.0001	10.07
4 hours	0.0002	9.45
2 hours	0.0004	8.83
1 hour	0.0008	8.21
30 minutes	0.0017	7.54
15 minutes	0.0033	6.95
10 minutes	0.005	6.58
5 minutes	0.01	5.96
1 minute	0.05	4.52
30 seconds	0.1	3.90
10 seconds	0.3	2.92
1 second	3	0.87
0.5 second	6	0.25
0.1 second	30	-

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Equipment and Hazards

- Engineering controls
  - Two contact points for operation
- the UVC germicidal LEDs include the integration of safety systems based on sensors and software that help protect the operator and other personnel from accidental UVC light exposure
  - Motion Detector
  - Gyroscope

Recommended Controls

Recommended administrative controls

- Signage
  - Caution: High Intensity Ultraviolet Energy. Protect Skin and Eyes.
- SOPS
- Training
- Barricades

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Lastly, PPE

- Sunscreen – Broad-Spectrum
- Protective clothing – minimize skin contact
- Eye protection
- Distance
- Polycarbonate face shield - ANSI Z87.1-1989 certification

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Face Shields

- The % Transmittance was used to calculate Maximum Safe Distances and Exposure Times when ANSI Z87.1 UV Protection Used

Exposure Duration (hours)	Distance from Source (feet)					
	U2	U2.5	U3	U4	U5	U6
8 hours	3.90	3.90	3.58	3.08	2.46	1.85
4 hours	3.28	3.28	2.96	2.46	1.85	1.23
2 hours	2.66	2.66	2.35	1.85	1.23	0.61
1 hour	2.05	2.05	1.73	1.23	0.61	-
30 minutes	1.37	1.37	1.05	0.55	-	-
15 minutes	0.78	0.78	0.46	-	-	-
10 minutes	0.41	0.41	0.09	-	-	-

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Conclusion

- Potential Exposures were evaluated
- Hazard Controls were identified
- The Hierarchy of Controls was introduced to the project team
- A CIH on the team allowed for a unique prospective.

Conclusion

- Questions?

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