UVC CLEANING SYSTEMS INC

Root Cause of Odor When Using UVC Disinfection

Summary:

UVC devices have been used for successful disinfection of air and surfaces in multiple industries, more specifically the healthcare industry. However, with the use of these devices it has been often noticed that there is a residual odor after disinfection, otherwise known as volatile organic compounds (VOCs). This odor has been described as a sulfuric smell similar to rotten eggs, garlic, or burning hair. A recent study by Dr. Normand Brais about residual odors from UVC disinfection has been published showing information on how UV irradiation of keratin and cysteine in dust particles from the air emit chemical byproducts of thiol and mercaptan molecules, which contain a significant amount of sulfur.

Potential Sources of Odor:

There are many possibilities as to the source of the odor following UVC disinfection that have been documented. These hypotheses include: off gassing of paint on wall surfaces, glue on UV lamps melting or overheating, or contact with air and surface dust. Nevertheless, off gassing of paint was negated once using UV devices in paint less rooms as well as the glue on UV lamps after it was revealed that removing the glue did not have any effect on the presence or absence of smell. The hypothesis of UV disinfection on air and surface dust was finalized after the study performed multiple tests in the same enclosure and after each test the odor seemed to decrease.

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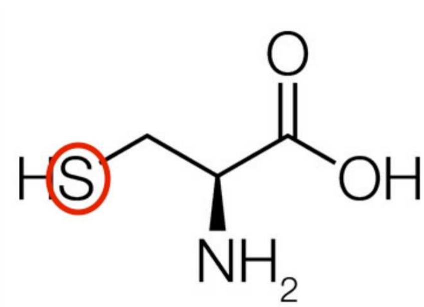
Composition of Airborne Dust:

Dust in human environments consists of around 80% dead human skin and hair cells, and the rest a small percent from environmental fibers, minerals, and cells.

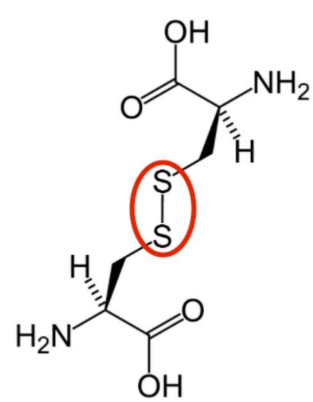
Measured Property	Measured	Target
Fibrous Fraction	Volume %	Volume %
Cotton Fibers	70-100%	83%
Synthetic Fibers	10-40%	9%
Hair	1-10%	8%
Particulate Fraction	Volume %	Volume %
Skin Cells	40-70%	62%
Construction Material and Soil	10-40%	12%
Plant Fragments	10-40%	16%
Starch	1-10%	4%
Low Temperature Combustion	1-10%	1%
Cotton	1-10%	<1%
Sugar	<1%	<1%
Hair	<1%	<1%
Rust	<1%	<1%
Paint	<1%	<1%
Fungal	<1%	<1%
Synthetic fibers	<1%	<1%

(Gipp)

The main components of dead human skin and hair cells are keratin and its amino acid, cysteine. Keratin is a fibrous protein found in skin cells on the outer layer of the human skin, hair, and nails. Cysteine is a sulfur containing amino acid typically found in dust particles due to being bound by keratin in hair. Keratin consists of a long chain of large amounts of cysteine that contains sulfur. Atomically, sulfur provides a site on the substances for the formation of a strong chemical bond with other molecules and thus allows for strength and stability to hold together keratin fibers.



Structure of Cysteine, contains sulfur (S) at the end of the chain



Cysteine bonded to another cysteine via a disulfide bond (two sulfurs bonded together)

7/19/16

UVC, Keratin, and Cysteine:

UVC light has high energy that can break chemical bonds and break larger molecules into smaller molecules. “The energy of germicidal UV photons at 254 nm wavelength is 470 kJ/mol” (Brais) and is higher than the average chemical bond energy (bond enthalpies) of all of the chemical compositions in keratin and cysteine. A higher energy potential of UV energy compared to the energy in chemical bonds allows for the breaking of these bonds (see table below). The broken chemical bonds between certain atoms may contain the remaining sulfur and will create a sulfur compound called thiol or mercaptan.

Average Bond Enthalpies (kJ/mol)

Single Bonds

C—H	413	N—H	391	O—H	463
C—C	348	N—N	163	O—O	146
C—N	293	N—O	201	O—F	190
C—O	358	N—F	272	O—Cl	203
C—F	485	N—Cl	200	O—I	234
C—Cl	328	N—Br	243		
C—Br	276			S—H	339
C—I	240	H—H	436	S—F	327
C—S	259	H—F	567	S—Cl	253
		H—Cl	431	S—Br	218
Si—H	323	H—Br	366	S—S	266
Si—Si	226	H—I	299		
Si—C	301				
Si—O	368				

(Kent)

Sulfur Compound Concentration Smell Threshold:

Thiols and mercaptans have an extremely low smell threshold and humans can easily detect thiols at extremely low concentrations. The breaking of multiple sulfide bonds, as listed in the table below, can give of a variety of different smells that the human nose can detect. Consequently, the smell after disinfection using a UVC device is the breaking of these bonds during sterilization.

Reported Sensory Threshold for Thiol / Sulfur Compounds[6]

Compound Name	Chemical Formula	Sensory Description	Smell Threshold (ppb)
Hydrogen Sulfide	H_2S	Rotten Egg, Sewage-like	0.5 - 1.5
Ethyl Mercaptan	CH_3CH_2SH	Burnt match, sulfidic, earthy	1.1 - 1.8
Methyl Mercaptan	CH_3SH	Rotten cabbage, burnt rubber	1.5
Diethyl Sulfide	$CH_3CH_2SCH_2CH_3$	Rubbery	0.9 - 1.3
Dimethyl Sulfide	CH_3SCH_3	Canned corn, cooked cabbage, asparagus	17 - 25
Diethyl Disulfide	$CH_3CH_2SSCH_2CH_3$	Garlic, burnt rubber	3.6 - 4.3
Dimethyl Disulfide	CH_3SSCH_3	Vegetal, cabbage, onion-like at high levels	9.8 - 10.2
Carbon Disulfide	CS_2	Sweet, ethereal, slightly green, sulfidic	5

(Brais)

Concentrations of thiol after UV disinfection end up being around 200 parts per billion (ppb) in volumetric concentration, and according to ASHE the "acceptable level for 8 hr exposure is 0.5 parts per million (ppm) or 500 ppb" (Brais). Therefore, levels of thiol concentration due to UV disinfection are deemed as safe to human exposure.

Conclusion:

The amount of human skin cells in dust concentrations due to human presence in areas that UVC devices disinfect is extremely high. With high levels of keratin and cysteine in the dust particles, the breaking of chemical bonds in both molecules causes the formation of sulfur containing thiols. With the low threshold of human detection to smell, thiols are the reason why UV devices cause a potentially unpleasant odor in rooms after disinfection.

References:

Brais, N., & Despatis, B. (n.d.). Root Cause to Odor Generated by UV Disinfection by Mobile Units (Rep.). Montreal, QC: Sanuvox Technologies.

Gipp, M. M., & Wietfeldt, J. R. (2007, July 12). Artificial dust composition and method of manufacture. Retrieved March 18, 2016, from http://www.google.com/patents/WO2007079027A2?cl=en

Kent. (n.d.). Bond Enthalpy (Bond Energy). Retrieved March 18, 2016, from http://www.kentchemistry.com/links/Kinetics/BondEnergy.htm