

UVC Energy: How Does It Work?

UVC energy's absorption by organic materials enables it to sanitize

Much like the sun's magnetic-wave energy, ultraviolet "C"-band (UVC) energy can kill microbes, degrade organic material, and have a regenerative and/or restorative effect on the air it irradiates. However, questions about UVC energy abound. This article will attempt to answer those questions by explaining how UVC energy works.

HISTORY OF UVC ENERGY

Since the late 1800s, UVC energy has been used successfully to disinfect both water and equipment. Its use in air-stream disinfection has been applied since the 1930s, with some anecdotal success in the 1990s.¹ During that time, low output of inefficient lamps was handicapped further by both hot and cold moving air, which changes the lamps' plasma temperature, and thus their mercury-vapor pressure. This further lowered the already-low production of photons at the 254-nanometer line. (The "C" band consists of short wavelengths between 200 to 280 nanometers.)

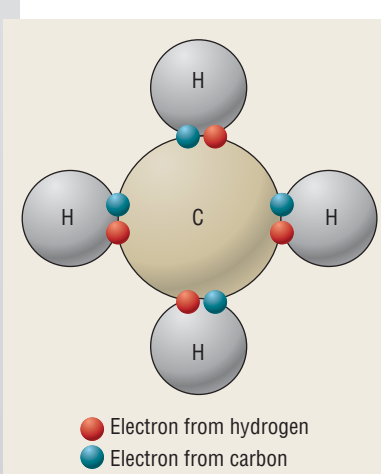


FIGURE 1. Covalent bonding.

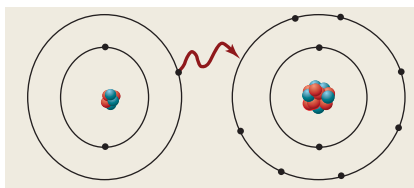


FIGURE 2. Ionic bonding.

Field lamp-output testing and microbial sampling were nonexistent or poor at best. The thought of establishing today's

mathematical relationships between UV fluence and microbial response in an air stream perhaps was only an ambition.^{2,3,4} Today, water, air, and surface disinfection is commonplace, and we can predict what will happen.⁵

Each new year provides a closer relationship between prediction and outcome.

ORGANIC MATERIALS

UV energy is "well absorbed" by biomatter and organic compounds, such as, tissue, cellulose, dashboards, and car tires. Contaminants in HVAC systems are composed of these same bio-based and/or organic structures.⁶

Organic-based materials, living or inanimate, are held together electronically by one or more bonds. A "covalent," or intramolecular, bond is characterized by the sharing of one or more pairs of electrons of mutual attraction⁷

(Figure 1). An "ionic" bond is an electrostatic bond between two oppositely charged ions (Figure 2). A weaker bond is the "hydrogen" bond, in which an attraction exists between two partial-electric charges of opposite polarity. A "chemical" bond is the physical phenomenon of chemical species being held together by atoms' attraction to each other through sharing and exchanging electrons or photons (Figure 3). The latter is of importance to this article and the physics of particle degradation in general. The good news is that these bonds also exist within macromolecules, such as proteins, nucleic acids, and deoxyribonucleic acid (DNA), or microbes.⁸ There

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are ways to tear bonds apart, such as chemical (bleach), heat (fire), or mechanical (UVC) methods. UVC energy is an ionizing radiation. Therefore, it deserves further investigation.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation (photons), X-rays, and gamma rays (Figure 4). Electromagnetic force holds electrons and nuclei together in atoms to make molecules (bonds). The attracting force can be affected when photon energy is transferred proportionally to its frequency and intensity to push or pull a molecule apart (Figure 5). The absorption of a photon by a molecule can change the equilibrium of a molecule's electronic configuration. Photochemistry only sounds complicated. Actually, it mirrors many common processes of attraction/degradation.⁹

PHOTODISSOCIATION

The number of electrons in an atom's outermost shell governs the atom's bonding behavior. Fewer electrons mean a less-stable atom; more electrons mean a more-stable atom. Moving these electrons to equilibrium can link atoms, which serves to build them into molecules. Reversing the process (i.e., take apart, disassemble, or disassociate) is the route of their destruction. Photodissociation is effective and exists all around us (such as lasers). For example, the Earth's ozone layer is formed by the photodissociation of ultraviolet light striking oxygen molecules and splitting them into individual oxygen atoms, which combine with unbroken oxygen (O²) to create ozone (O³). The same UV energy causes

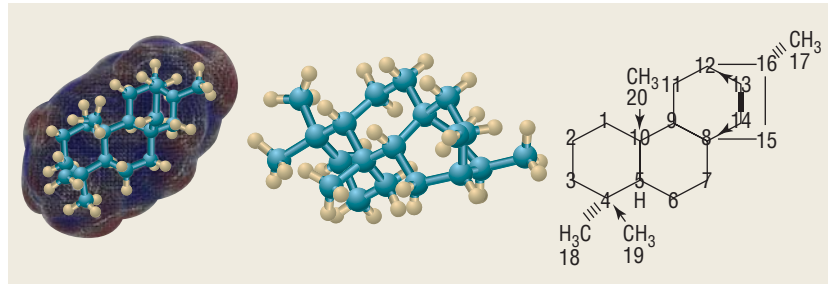


FIGURE 3. Organic molecule held together by chemical bonds.

photolysis of the ozone to pull it apart. This continual process of “making and destroying” keeps the ozone layer “alive” and dense and, therefore, capable of protecting us from vast forms of electromagnetic energy.¹⁰

IONIZATION

Ionization is the physical process of changing the number of electrons. Photolysis results from ionizing radiation in which a photon carries enough energy to remove completely an electron from an atom's outermost shell. The direct process can be defined as the interaction of one photon with one target molecule. UVC energy is the utmost form of this energy and, therefore, is the most efficient energy in this process. When enough of these ionizations occur, it is destructive to organic matter, especially living tissue and DNA.¹¹ This highly energetic radiation directly can cause the separation or degradation of bonds (such as chlorine, which disinfects via molecular destruction).

The scientific reference to this process is “population inversion.” It occurs when a system, such as a group of organic atoms or molecules, is exposed to UVC energy. An electron bound to an atom or molecule absorbs enough photon energy from an external UVC source to escape from the electric potential that originally confined it.¹² Visible light is similar: Molecules ionized by it react nearly spontaneously, such as with photographic film.

To look at this more clearly, let us examine the excimer UV laser.¹³ In this laser, UV energy is coherent (adds photons constructively to subtract electrons destructively) and is well absorbed by biomatter and organic compounds. Laser assisted in-situ keratomileusis (LASIK) UV lasers are well-focused collimated beams of energy capable of

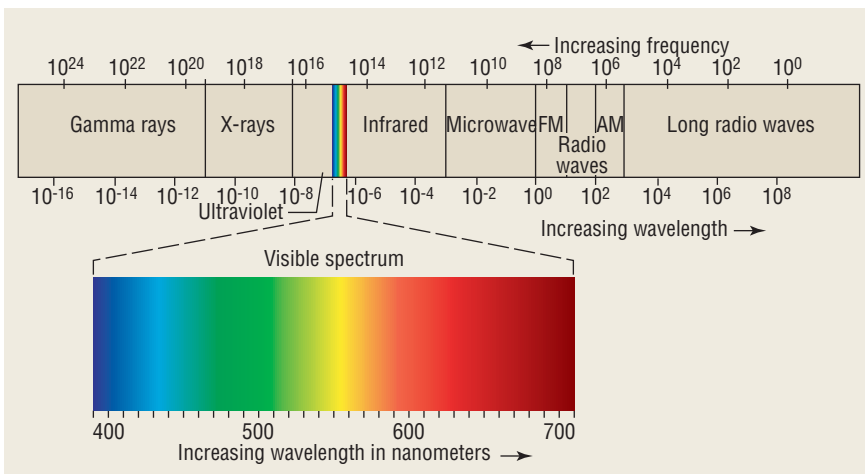


FIGURE 4. Electromagnetic spectrum.

removing extremely thin layers of corneal tissue without damaging adjacent areas. It does not generate heat. Instead, it turns tissue into gas and vapor by breaking various bonds. Another laser transmits UV energy through a quartz fiberoptic catheter and turns arterial-wall plaque and abnormal tissue into gas and vapor without harming surrounding healthy tissue.¹⁴ UV-laser ionization radiation disrupts molecular bonds to disintegrate organic structures through ablation (vaporization) rather than scorching.¹⁵

CONCLUSION

Similarly, low-pressure mercury-vapor lamps used for the inexpensive production of UVC light possess similar energy, though it is less focused. It can be confirmed that we photodissociate microbial DNA and then eventually its carcass when we inactivate, kill, or vaporize it.¹⁶ If this had not been witnessed firsthand over the last 100 years, we might struggle over the process. Let us recall that an HVAC-coil-style UVC system operates 24 hr a day, seven days a week, 365 days a year, which cumulatively provides 6 million microwatt seconds of extremely high-energy UV—from only a 1-microwatt source of output—over a 30-day period. Theoretically, this is enough energy to vaporize a pound of HVACR crud.¹⁷ This makes a profound case for a consumer that highly publicized, expensive, custom, or high-output lamps simply are not required to get that job done.¹⁸

Assumptions abound, but the truth is that science has not put forth a microbe that totally is resistant to the destructive effects of UVC energy. Only a few man-made materials actually can escape it—temporarily at that. The question is how little exposure is required before irreparable destruction occurs. In other words, the question is not whether UVC energy works, but where it can be used.¹⁹ The list of places is long. Imagine if every air-handling device of every kind were equipped with UVC. The orders of magnitude of inactivated infectious agents in a unit period of time are far too great to fathom. One could only wonder about the reduction of disease and absenteeism or the increase in productivity or, beyond that, the reduction of maintenance and increase in efficiency it may provide systems so equipped.^{20, 21, 22} The potential return of heat-exchange efficiency from the inability of organic material to bond or stay bonded together on heat-exchange surfaces may be anecdotal for now. But it is not about system energy-efficiency ratio (EER) or that the energy in vs. the

energy out is in compliance for a given tonnage. Instead, it is about a machine that currently calculates energy out as 15 tons, but was sold and installed originally as a 20-ton machine. A revamp is needed, starting with the machine's heat exchanger.

This article represents only part of the many reasons for the prominent inclusion of UVC energy in federal agencies, such as the Centers for Disease Control and Prevention, Environmental Protection Agency, General Services Administration, and National Institute for Occupational Safety and Health. They are worthy of mention. Adding the Department of Defense, Edgewood Area of Aberdeen Proving Ground, Air Force, Army, Navy, Homeland Security, and the space program, UVC energy deserves major attention. Two ways to assist these efforts would be to support the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE's) Technical Group on Ultraviolet Air and Surface Treatment (TG2.UVAS) committee and the International Ultraviolet Association (IUVA). TG2.UVAS already has been asked to provide a chapter in the ASHRAE Handbook. Additionally, ASHRAE Standard 52.2, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*, and GSA's UV-test protocol are to be modified for adoption into ASHRAE SPC 185P, *Method of Testing UVC Lights for Use in Air Handling Units or Air Ducts to Inactivate Airborne Microorganisms*. IUVA has put forth language for a myriad of standards for ultraviolet energy.

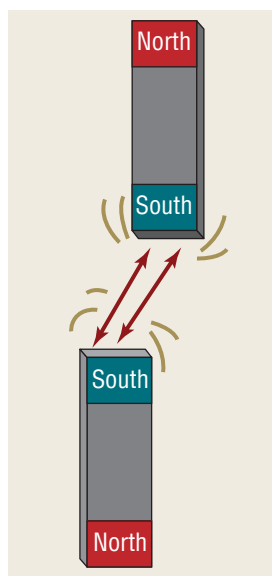


FIGURE 5. Atoms/molecules of like charges repel.

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