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TBPI Soft Ionization Compared with Ultraviolet Germicidal Irradiation

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Abstract

Ultraviolet germicidal irradiation (UVGI) and Targeted Bipolar Pulsed Ionization (TBPI) use different mechanisms. UVGI uses ultraviolet radiation for microbial inactivation; TBPI is designed for controlled ion delivery and charge-related contaminant interactions. UVGI performance and indoor-air effects vary with wavelength, dose, airflow, ventilation, background chemistry, surfaces and configuration [1, 2, 3, 4, 5, 6]. The absence of a UV mechanism in TBPI does not establish its efficacy or complete emissions profile. This paper compares mechanisms, operating considerations and the evidence needed to choose and evaluate an application, without a universal safety, energy or indoor-air-quality ranking.

1. Introduction

UVGI is used for germicidal treatment, while TBPI is designed to influence contaminant interactions through controlled ion output. A claim that TBPI reduces a biological contaminant requires an applicable model-specific test with a defined organism, method and outcome.

UVC germicidal systems use ultraviolet photons, commonly around 254 nm or 222 nm, to damage microorganisms. The germicidal effect occurs because UV photons can damage nucleic acids and other biological molecules, reducing the ability of bacteria, viruses, and fungi to reproduce or remain infectious. This makes UVC useful for air-stream disinfection, upper-room germicidal irradiation, surface disinfection, and coil irradiation.

TBPI does not rely on ultraviolet photon energy. TBPI is a soft ionization technology designed to generate controlled ion output and tune polarity toward target contaminant classes. Instead of using photon-driven chemistry to damage biological molecules or oxidize contaminants, TBPI uses charged species and electrostatic interactions to influence contaminants.

UV radiation can interact with biological targets and, depending on wavelength and conditions, with other species or surfaces in the treatment environment. These interactions should be considered alongside the intended germicidal benefit.

TBPI is designed to avoid UV-driven photochemical pathways because it does not irradiate air or surfaces with germicidal ultraviolet energy. That design distinction is relevant when comparing mechanisms, but it does not establish that every UVC application produces problematic byproducts or that TBPI is universally safer. UVC outcomes depend on wavelength, device design, dose, ventilation, background chemistry, and operating conditions.

2. How UVC Works

UVC germicidal systems use short-wavelength ultraviolet radiation to damage microorganisms. Traditional low-pressure mercury lamps often emit near 254 nm. Newer far-UVC systems commonly emit near 222 nm. Both wavelengths can be germicidal, although they differ in penetration depth, photochemistry, ozone-generation potential, and exposure considerations.

Germicidal UV can alter biological molecules and reduce the ability of microorganisms to reproduce or remain infectious. Its interactions with other indoor species depend on wavelength, absorption, dose and chemistry; germicidal effectiveness alone does not specify the magnitude of any secondary-chemistry effect.

Depending on wavelength and conditions, UV-related indoor chemistry can involve:

- oxygen;
- ozone;
- water vapor;
- VOCs;
- skin oils;
- cleaning residues;
- surface films;
- indoor particles;
- building material emissions.

A 2023 study of a commercial high-intensity UVC disinfection device found that UVC operation caused dramatic increases in particle number concentration and increases in many monitored gas-phase species [1]. Other studies of 222 nm germicidal UV have

shown ozone generation in both chamber and real-world settings [2, 3]. A 2024 study specifically reported ozone formation, ultrafine particle formation, and changes in VOC levels from 222 nm germicidal UV lamps in indoor office spaces [4].

This does not mean UVC has no place. It means UVC should be evaluated as an active photochemical technology rather than assumed to be chemically neutral. Depending on wavelength, intensity, ventilation, background VOCs, surfaces, and operating conditions, some UVC/far-UVC applications may alter indoor chemistry or generate byproducts. Those effects should be assessed against the intended germicidal benefit for the specific installation.

3. UVC and Ozone Formation

Ozone formation is an important consideration for some germicidal-UV configurations, particularly those operating at 222 nm. The wavelength and the actual device should be specified rather than treating all UVGI systems as equivalent [2, 3].

At 222 nm, photons are energetic enough to photolyze oxygen-containing species and initiate ozone formation pathways. Link et al. reported that 222 nm germicidal UV light can produce ozone in air and noted that ozone is undesirable indoors because of both health impacts and its ability to degrade indoor air quality through oxidation chemistry [2]. Peng et al. also reported significant ozone production from 222 nm germicidal UV lamps and found ozone formation across multiple commercial lamps [3].

Ozone matters for two reasons. First, ozone itself is a regulated respiratory irritant. It can irritate the lungs and airways, especially in sensitive populations. Second, ozone is chemically reactive. Once formed indoors, ozone can react with VOCs from cleaning products, fragrances, human emissions, building materials, and furnishings. These reactions can produce aldehydes, organic acids, oxidized VOCs, and secondary organic aerosol. Indoor chemistry reviews have long recognized ozone-initiated chemistry as an important source of secondary indoor pollutants [6].

TBPI avoids this specific risk pathway because it is not based on oxygen photolysis. TBPI does not use 222 nm or 254 nm photons to irradiate indoor air. Its purpose is controlled ion delivery rather than UV-driven photochemical disinfection. As a result, TBPI does not create the same ozone-generation mechanism associated with far-UVC lamps.

4. UVC, VOCs, and Ultrafine Particles

Published studies report changes in VOCs and particle number under some UVC and far-UVC operating conditions [1, 4, 5]. These results should be interpreted in the context of the tested configuration.

Graeffe et al. studied a commercial high-intensity UVC device and reported increases in particle number concentrations and increases in many gas-phase species during UVC operation [1]. This is important because it shows that UVC can do more than inactivate microorganisms. It can also trigger chemical and particle formation processes in indoor air.

Sørensen et al. studied 222 nm germicidal UV lamps in indoor office spaces and reported formation of ozone, ultrafine particles, and alterations in VOC levels [4]. This is directly relevant to occupied-space applications because 222 nm far-UVC is often promoted as suitable for use in occupied rooms.

Carter et al. modeled the impact of UVC light on indoor air chemistry and found that germicidal UV can alter indoor oxidant chemistry, including chemical pathways involving ozone, hydroxyl radicals, and VOC oxidation products [5]. This supports the broader point that germicidal UV is not chemically neutral in indoor environments.

The formation of ultrafine particles is especially important. Ultrafine particles are small enough to penetrate deeply into the respiratory system. Their health impacts depend on concentration, chemistry, exposure duration, and particle composition, but their formation should not be ignored in air-cleaning evaluations.

TBPI does not rely on photolysis of VOCs or surface films. It does not shine high-energy UV photons onto indoor air, skin oils, surfaces, or cleaning residues. Therefore, TBPI avoids the UV-driven pathway that recent studies have associated with VOC changes and ultrafine particle formation.

5. UVC and Surface Chemistry

UVC systems can affect more than the air stream. UV photons can strike surfaces and surface films. In real indoor environments, surfaces are not chemically clean. They contain skin oils, cleaning chemicals, plasticizers, fragrances, cooking residues, dust, and adsorbed VOCs.

UV exposure can affect surface materials and films, with possible changes in gas-phase emissions. The extent depends on the material, wavelength, exposure and ventilation.

Findings from a high-intensity device or one occupied-room configuration should not be generalized to every UV installation [1, 4, 5].

TBPI does not use UV lamps or irradiate surfaces, so it does not create the same UV-photolysis pathway described in these studies. That mechanism-level distinction should not be read as a blanket conclusion that every UVC installation creates adverse chemistry or that TBPI has no other emissions considerations; those outcomes require application- and product-specific evidence.

6. Direct Exposure and Maintenance Differences

UVC also has direct safety and maintenance considerations that TBPI does not share.

Traditional 254 nm UVC can damage skin and eyes if people are exposed directly. This is why 254 nm systems are usually installed inside air handlers, inside ductwork, in enclosed chambers, or in upper-room configurations with careful shielding and commissioning. When installed inside air handlers or ductwork, electrical safety interlocks are highly recommended to de-energize the UVC when the access compartments are opened.

Far-UVC at 222 nm has been promoted as safer for occupied spaces because it penetrates less deeply into skin and eye tissue. However, the indoor chemistry literature shows that even when direct tissue exposure risk is reduced, air-chemistry concerns can remain [2, 3, 4, 5].

UVGI systems require maintenance and verification of delivered output. Depending on the system, lamps can age or foul, reflectors can degrade, and replacement is needed. Mercury-containing lamps require suitable handling and disposal; UV LEDs have different thermal-management and service requirements. Use manufacturer-specific service intervals and verified output rather than a universal lamp-life assumption.

TBPI does not require a germicidal-UV exposure field. Its verification requirements include electrical and installation safety, available polarity/timing controls, ion delivery, emissions and the intended contaminant outcome. Maintenance remains model-specific.

7. TBPI as a Soft Ionization Alternative

TBPI is best described as a soft ionization technology. It is designed to control ion polarity and timing rather than expose air or surfaces to germicidal ultraviolet radiation.

The key TBPI differences are:

Controlled polarity

TBPI can bias ion output positive or negative depending on the contaminant being targeted.

Pulsed operation

TBPI can separate positive and negative generation in time. The intended reduction in immediate recombination and any improvement in downstream ion delivery require testing under defined operating conditions.

No UV photon exposure

TBPI does not use 222 nm or 254 nm radiation, so it avoids UV-driven photolysis of oxygen, ozone, VOCs, surface films, and cleaning residues.

No intended VOC oxidation

TBPI is not designed to deliberately oxidize VOCs. This is a statement of design intent, not proof that all partial-oxidation products or other emissions are absent. Verify relevant compounds and endpoints with applicable model-specific testing.

Ozone-generation mechanism from UV photolysis

Because TBPI does not use far-UVC photons, it avoids the oxygen-photolysis pathway associated with ozone production from 222 nm germicidal lamps [2, 3].

Occupied-space compatibility

Occupied-space suitability depends on the specific system and application. TBPI does not use germicidal UV radiation, while UVC/UVGI systems can also be applied safely when wavelength, shielding, exposure, ventilation, dose, maintenance, and commissioning are appropriately engineered and verified.

8. Comparative Summary

Issue	UVC / UVGI	TBPI / AEIRO
Mechanism	UV exposure intended to inactivate microorganisms.	Controlled ions and polarity/timing strategy.
Wavelength	Common examples include 254 nm and 222 nm; effects differ.	No germicidal-UV wavelength.
Exposure	Controls depend on wavelength, dose and configuration.	No germicidal-UV exposure; electrical and installation safety still apply.
Ozone	Assess the specific wavelength, device and installation.	Use model-specific ozone evidence. UL 2998 addresses a 0.005 ppm (5 ppb) threshold [7].
VOC / particle effects	Secondary chemistry has been reported under some tested conditions.	No blanket byproduct or reduction claim; verify the stated emissions and treatment endpoints.
Surfaces	Exposed films/materials may respond to UV, depending on conditions.	No UV-photolysis pathway; this does not establish all other emissions outcomes.
Maintenance	Output verification, cleaning and replacement depend on the system.	Follow the applicable model's instructions; no universal maintenance-free claim.
Application / energy	Compare equivalent treatment objectives, airflow, runtime and power.	Compare equivalent treatment objectives, airflow, runtime and power.

These comparisons describe mechanisms and evaluation criteria, not technology-wide certifications. UL 2998 addresses ozone emissions and does not establish all byproducts or efficacy. Numerical energy ratios require a like-for-like treatment objective, coverage or airflow, duty cycle, runtime and measured product power.

9. Conclusion

UVGI and TBPI should be selected according to the treatment objective and the evidence available for the proposed installation.

UVGI can inactivate microorganisms, while some studied configurations also affect indoor chemistry [1, 2, 3, 4, 5, 6]. Evaluate the relevant wavelength, dose, ventilation, surfaces and background compounds alongside the intended germicidal benefit.

TBPI is a soft ionization technology. It does not use germicidal ultraviolet light or UV-driven photochemistry. That makes its mechanism materially different from UVC/UVGI, but the comparison should remain application-specific. UVC can be effective when properly designed, applied, and maintained, while its air-chemistry effects depend on wavelength, intensity, ventilation, surfaces, and surrounding compounds. TBPI should likewise be evaluated using product-specific emissions and performance evidence. The most appropriate approach depends on the intended treatment objective, installation conditions, and validated performance rather than a universal claim that one technology is safer or produces better IAQ in every case.

References and source types

Research citations provide background for the stated mechanisms and tested systems. They do not automatically validate AEIRO product performance. Manufacturer literature, public guidance and internal references are labeled separately. Product claims require evidence for the relevant model, endpoint and operating conditions.

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