UV-C LED for Water Purification

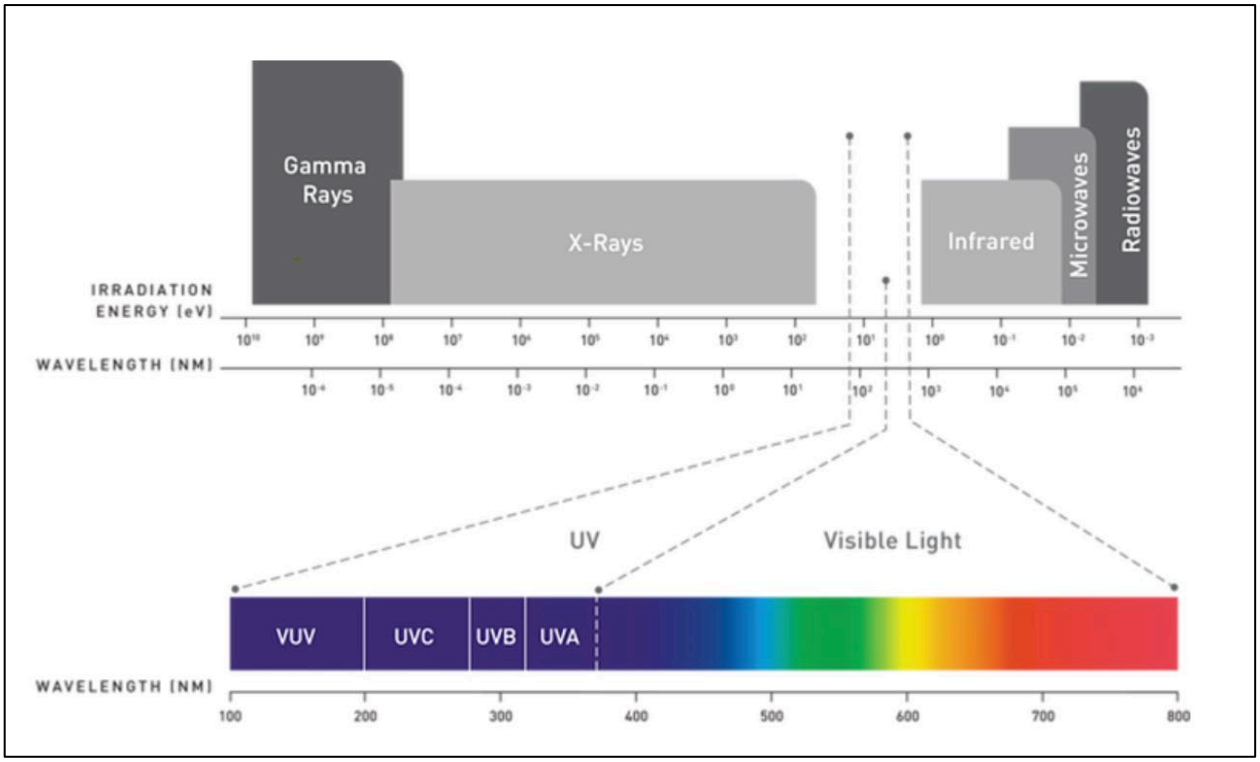
Water purification remains a prevalent issue in the world today. In many third world countries, drinking water is easily polluted and can lead to the mass infestation of various pathogenic microorganisms in vital water sources. The consequences of polluted drinking water could be catastrophic and lead to global viral pandemics.

UV-C presents an innovative solution for providing clean and effective water purification.

But just how effective is this relatively new technology and can it provide the solutions we need now and for the future?

What is UV-C?

UV-C (ultraviolet) light is a type of radiation that can be found on the electromagnetic spectrum and is measured in Nano-meters (nm). Invisible to the human eye, UV-C is an effective disinfectant due to the density of its wavelength.



There are three ranges to UV light – UV-A, UV-B, UV-C and Vacuum-UV:

- **UV-A** – otherwise known as black light, it has the longest wavelength, ranging between 315nm to 400nm.

- **UV-B** – known as the medium wavelength, it ranges between 280nm and 315nm.
- **UV-C** – the shortest wavelength, it ranges between 200nm and 280nm.

UV-C is germicidal, meaning it can be used effectively as a disinfectant to kill microorganisms, such as bacteria and viruses.

When the DNA of microorganisms absorbs UV light, it stops them from being able to reproduce and duplicate, thereby preventing their growth.

In recent years, LEDs have been developed to emit UV-C radiation as an alternative to mercury-vapor lamps.

What is a UV-C LED?

Light-emitting diodes (LEDs) are semiconductor devices that are made up of multiple layers of substrate materials. They can be designed so that a wavelength can be inputted and emit photons in the UV-C range that can be used to stop the replication of bacteria.

UV-C LEDs perform the same functions of conventional mercury-vapor lamps but have many benefits in comparison.

- **Environmentally friendly** – conventional UV lamps use heavy metals that are difficult to handle and cost a great deal to dispose of safely
- **Small design footprint** – LEDs are much more compact compared to their mercury-vapor counterpart, meaning they can be integrated easily into new innovative designs.
- **Instant-on/off** – UV-C LEDs work instantly, so there is no need for a warm-up time that is a common constraint of mercury-vapor lamps
- **Unlimited cycling** – on/off cycles do not impact the life of the LEDs, meaning there is an unlimited scope for lamp cycling.
- **Temperature independent** – LEDs can emit photons from a different surface as their heat emissions. They can be designed so that if UV-C LEDs are being used in water purification, they will not transfer heat into the water.
- **Wavelength selection** – One of the greatest benefits of UV-C LEDs is that users can configure them to choose a specific wavelength that is best suited for maximum absorption of light for the chosen microorganism.

How does UV-C LED disinfection work?

Different types of UV-C disinfection can work depending on the scale of the solution being implemented. However, the principles of how UV-C disinfection works remain the same.

Due to the rapid development of the smartphone, we now have access to more advanced LED systems that can emit not just visible light but also infrared and UV.

An LED produces a pre-selected wavelength from a small amount of electricity. The LED then emits UV-C photons through the water that penetrate the cells and damage the nucleic acid in the microorganism DNA.

As these cells cannot replicate, it renders the harmful microorganism inactive. As a result, UV-C LEDs allow for high-intensity radiation to kill the bacteria in seconds, and its effectiveness is measured in LOGs.

Disinfection of drinking water

One area where UV-C LEDs are proving to be successful is in the disinfection of drinking water.

UV-C LEDs are being to disinfect drinking water at various points in the treatment cycle, from source to consumption. It can take a few seconds for the water to become clean in a UV-C model, and the new technology allows for LEDs to placed at a different point to ensure decontamination.

It works initially when a water reservoir is exposed to a number of high-powered LEDs that disinfect the water. They emit powerful UV-C photons in the range of 200 – 280nm that pass through the water, stopping the bacteria in the water from being able to reproduce.

Many newer systems have taken advantage of the compact size of the LEDs and can disinfect at the end stage of the drinking water journey – ensuring complete disinfection.

Water treatment and pathogen control

A recent paper released in *Science of the Total Environment* journal looked at various microbial disinfection methods for UV-LED water treatment systems. It found that UV-C LEDs were effective in the inactivation efficiency and energy consumption of UV-LEDs for pathogens at various wavelengths.

As UV-C LEDs can select various wavelengths to target specific microorganism present in infected water and deactivate them, different pathogens and bacteria stop replicating when they have been exposed to different wavelengths.

Read the full paper here: *Evaluation survey of microbial disinfection methods in UV-LED water treatment systems*.

What is LOG reduction?

LOG reduction is used to measure how thoroughly a decontamination process reduces the amount of contamination.

For example, 1-log reduction means the number of bacteria is 10 times smaller, 2-log equals 100 times smaller, 3-log equals 1,000, and so on.

To put this into perspective, if a surface had 100,000 microbes present, it would take 5-log reduction to bring the number of microorganisms down to just one.

How effective are UV-C LEDs?

UV-C LEDs have proven to effective, but its success at inactivating microorganisms is dependent on several factors, as the paper, *Evaluation survey of microbial disinfection methods in UV-LED water treatment systems*, found.

While UV-C LEDs have been found to stop the replication of viruses, bacteria, and other microorganisms, its effectiveness is dependent on the UV dose and time of exposure.

Different microorganisms absorb the UV light at varying wavelengths and can take longer than other bacteria to fully absorb the UV-C radiation.

Therefore, if you know what pathogen is present in a contaminated water source, you can program your LED to produce the wavelength that is best suited to stopping that microorganism from replicating.

While UV-C LEDs have proven to be effective, the more information you can obtain from the contaminated source allows the LED to be more effective at neutralizing the pathogens.

Applications of UV-C LEDs

There are many applications where UV-C is LEDs are being tested to see if they can become a solution to not just current disinfection challenges but our future ones too.

Drinking water disinfection, water purification, and treatment are where the technology is gaining traction as the solution is chemical-free, has no risk of creating harmful by-products, is an effective pathogen inactivation, and is very low maintenance.

As well as water, UV-C LEDs are offering disinfection for both air and surfaces. UV-C LED air purifiers for HAVC (heating, ventilation, and air conditioning) are being used increasingly in the commercial landscape.

There are numerous applications, from residential to commercial, healthcare, transport, life sciences, defence, and emergency response where UV-C LEDs are finding new uses:

Market Segment	Example Applications	UV-C LED system benefits: Top 3 important attributes valued by segment
Residential	POE, Appliances, Faucets	Ultra-compact footprint, Plug and play (e.g. easy to retrofit), Low power draw
Commercial	Food and beverage service, Water dispensers and fountains	Ultra-compact footprint, Low power draw, No heating of water
Healthcare	HAI control, Dialysis, Dental	Mercury-free, Chemical-free, Durable (e.g. vibration resistance)
Transportation	RV and boating, Automotive, Aviation, Space	Chemical-free, Durable, Lightweight
Life Sciences	Bio-pharma, Ultrapure water	Point-of-use distribution, Mercury-free, Chemical-free
Defense/Emergency Response	Personal hydration, Remote treatment	Ultra-compact footprint, Lightweight, Durable (e.g. vibration resistance)

In terms of solving our future problems, UV-C LEDs are being considered in human space exploration, for disinfection applications.

Current systems used in space exploration require water to be recycled. Should bacteria be allowed to fester, it can have life-or-death ramifications.

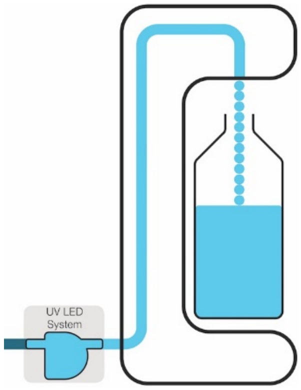
By incorporating advanced UV-C LED disinfection technology, it can be used to make the recycling of these systems more efficient, more reliable, and more practical. Meaning there are new possibilities for waste treatment and environmental control – not just on earth.

Types of UV-C LED disinfection systems

UV-C LED technology is now being used for water dispensing and water-cooling applications and requires expertise, experience, and significant engineering knowledge to integrate this technology.

To date, there have been three types of disinfection system concepts for integrating UV-C LED systems.

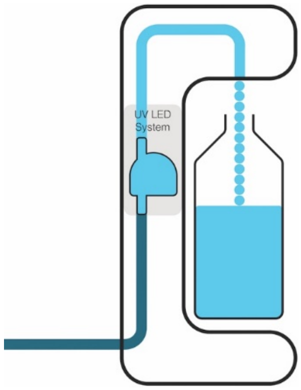
Inlet disinfection system



For pre-existing water systems, the disinfection process is often left outside of the device, which can leave an opening for bacteria to grow at any point in the system. In the inlet model, the UV-C LED is easy to replace and will last considerably longer than its mercury-vapor counterpart.

While there is no need to redesign existing systems, the trade-off of having an inlet system is that the components are visible and are therefore more susceptible to damage.

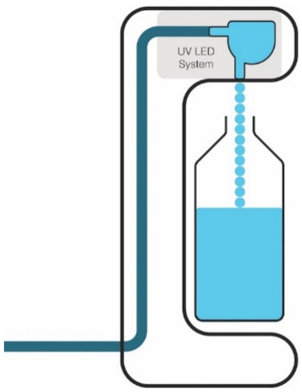
In process disinfection



In this configuration, UV-C LEDs are integrated into the current system. This set up has several benefits: the UV-C LED component is protected, the amount of contamination between unit and dispenser is significantly reduced, and this model makes use of the compact nature of the LEDs.

The one major drawback to the in-process disinfection model is that it is susceptible to retrograde contamination and bacteria growth up the pipeline.

Point of consumption disinfection



This system offers the greatest amount of protection by taking advantage of the full attributes of UV-C LED technology. Installed at the point of consumption, the system features an instant on/off switch. Point of Consumption disinfectant systems have the most benefits, but due to the complexity and expense of the new system, they are the most complicated to install and design.

They can become contaminated by an external source, in which the bacteria can grow through the pipe into the system. This can be prevented by the regular cycling of the system.

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