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# UV Glossary

## Paper

## Sustainable water treatment

UV Alliance
Center of expertise for UV treatment

# UV Glossary

To be able to understand each other, we need to speak the same language. We need to use terminology in a uniform way to create a good understanding of what we say, why and how we actually apply it in practice. Speaking a consistent language all members understand and use with the same meaning and context every time is key to get our message across.

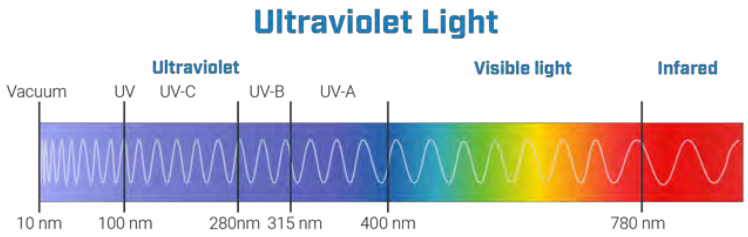
For that reason, we created a UV Glossary with definitions and explanations of UV-related terms.

# 1: Ultraviolet germicidal irradiation

Ultraviolet germicidal irradiation is the use of Ultraviolet light UV-C for disinfection purposes.

**UV light:** Ultraviolet light is a type of electromagnetic radiation of wavelength of 10-400nm and is not visible by the human eye. UV light is produced by the sun or artificial means within the wavelength range of 10-400nm.
The spectrum of Ultraviolet light starts at violet visible light and ends at Röntgen radiation (X-rays) and divided can be subdivided into 3 ranges:

- UVA: 315 – 400 nm (Non germicidal, Blacklight, Tanning)
- UVB: 280 – 315 nm (Germicidal)
- UV-C: 100 – 280 nm (Germicidal)
- VUV: 10 – 100 nm




*Electromagnetic spectrum from 10nm to 1000nm*

**UVA:** Long wave UV, soft UV with a wavelength of 315 – 400nm, not absorbed by the ozone layer. UVA radiation from the sun makes up 95% of all UV rays reaching the earth's surface. UVA penetrates deep into our skin and damage it, resulting in a tan. It causes almost all forms of skin aging, including wrinkles.

**UVB**: Medium wave UV, intermediate UV with a wave length of 280 – 315nm, mostly absorbed by the ozone layer. UVB radiation makes up only 5% of the UV rays from the sun, but it is very high energy.
UVB does not penetrate as deeply as UVA, but it can wreak havoc on the top layers of your skin. UVB damages skin cells and causes DNA mutations that can eventually lead to melanoma and other types of skin cancer. UVB radiation from the sun also can cause cataracts.

**UV-C:** Short wave UV, hard UV with a wavelength of 100 – 280nm, completely absorbed by the ozone layer and atmosphere. This UV light is produced by artificial lighting (i.e. UV lamps) and used for disinfection, photolysis and water treatment. UV-C radiation breaks the DNA of bacteria, viruses and spores, rendering them harmless without chemicals. UV-C light is hazardous and needs protective measures for use and also called germicidal UV for its disinfection applications. UV light with a wavelength of 185nm produces ozone and 254nm destroys ozone.

**VUV (Vacuum UV):** Very short wavelength UV light with a wavelength of 10-200nm. Vacuum UV can only be used and produced effectively in a vacuum environment as well as in an inert gas environment (absence of oxygen) because it is absorbed by air (oxygen) and so generates ozone. Has niche uses in science and cleaning.

# 2: UV Disinfection System

An UV disinfection system consists of a Reactor, UV lamps, Ballast (or Lamp driver), controllers and sensors to inactivate microorganisms such as bacteria, viruses, and protozoa without the use of chemicals.

## 2.1 Reactor

**UV Transmittance (UVT):** A measurement of the amount of UV-C light passed through a water sample, expressed as a percentage of the amount of UV-C light passed. It is usually measured over a path length of 10mm but also over path lengths of 2mm, 40, 50mm and 100mm.
Example: UVT10mm = 90% means 90% of the UV-C light is passed through 10mm water.

Transmittance is generally monitored to determine the effectiveness of a UV disinfection system. Be aware that in some countries T10 means through 10 cm, so a better expression would be f.i. $T_{10mm}$.

**UV Absorbance (A):** A Measurement of the amount of UV-C light absorbed by a water sample. In contrast to transmittance, absorbance expresses the amount of light absorbed on a logarithmic scale. Absorbance is usually measured to indicate the concentration of organic compounds in a water sample.

UV Transmittance and Absorbance are both measured at a certain wavelength, for UV lamps at 254nm.
Absorbance A is the negative logarithm of transmittance T, in formula: $A = -\log T$.
Example of the relationship between Transmittance and Absorbance:

| Transmittance | % Transmittance | Absorbance |
|---|---|---|
| 1 | 100 | 0 |
| 0.1 | 10 | 1 |
| 0.01 | 1 | 2 |

**Spectral absorption coefficient SAC:** a measure of the attenuance of UV radiation to passing through an optical medium which has been filtered;

**Spectral attenuance coefficient SAtC**: a measure of the attenuance of UV radiation to passing through an optical medium.

- This value can be converted to UV transmittance;
- It concerns unfiltered water.

**Turbidity:** The amount of UV light blocked in water by dispersed microscopic particles and colloids and can be expressed in NTU (Nephelometric Turbidity Units) or FNU (Formazin Nephelometric Units). Turbidity cannot be used to determine the UV transmittance or absorbance of the water. Can also be expressed as scatter coefficient (in combination with SAtC);

**UV-C-dose:** A product of incident intensity multiplied by exposure time to give a widely usable "amount" of UV-C applied. In comparable cases one can expect that the same UV-C-dose has the same effect. For disinfection the most commonly used UV-C-dose is 300J/m². UV-C-dose is expressed as J/m² or mJ/cm².

**Computational Fluid Dynamics (CFD):** Modelling technique to predict the performance of the water flow and pressure of an UV reactor to improve the inactivation of microorganism and optimise the UV-C-dose.

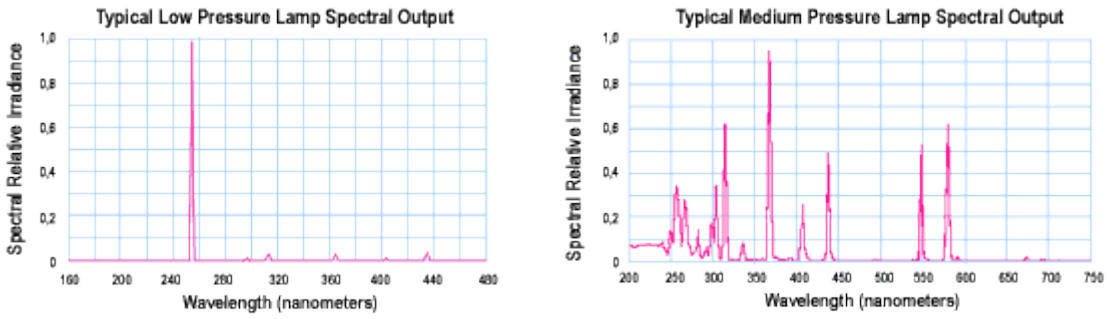
## 2.2 UV Lamps

Ultra violet lights are designed to emit ultraviolet radiation, a form of electromagnetic radiation, with wavelengths in the ultraviolet (UV) range, which is shorter than visible light, although longer than x-rays. For germicidal application these lamps are optimized for a wavelength of 254nm. For ozone applications, lamps are optimized for a wavelength of 185nm. Most commonly used UV lamps for disinfection applications are low and medium pressure lamps.

**Low pressure lamp:** A mercury discharge lamp made of high grade quartz that emits a narrow spectrum of UV-C light with a peak at 254nm that is efficient against microorganisms. Low pressure lamps are defined by having a lower internal pressure as medium pressure lamps. This causes the light to be emitted as a monochromatic spectrum meaning it has a single wavelength ("colours") of light. Technically low pressure lamps are polychromatic like medium pressure lamps, however the other peaks (with shorter wavelengths) are in disinfection applications filtered away or (in case of longer wavelengths) emitted as visual light. Low pressure lamps have a significantly higher radiant efficiency and lifetime than medium pressure UV-C lamps making them more sustainable. Available power is generally lower (100W to 1000W) than that of medium pressure lamps, however in most practical cases this is off-set by it's significantly higher radiant efficiency. For optimum efficiency, it is important to keep the lamp temperature low.

**Medium pressure lamp:** A mercury discharge lamp made of high grade quartz that emits a broad spectrum of UV-C light that is partly efficient against microorganisms. Medium pressure lamps are defined by having a higher internal pressure as low pressure lamps. This causes the light to be emitted as a polychromatic spectrum meaning it has a significant portion of multiple wavelengths ("colours") of light. Medium pressure lamps have a lower radiant efficiency and lifetime than low-pressure UV-C lamps, however they are available in higher power (380W up to 36kW) at relatively low cost related to its UV-C output.

Typical spectrum of low and medium pressure UV lamps:




**UV-LED:** A relatively new technology that uses Light Emitting Diodes colloquially known as LED-lamps to produce UV-C light at wavelengths of 265-280 nm. Currently UV-C LEDs are less efficient and powerful than other lamp technologies, however this is expected to improve in the future. This technology is most commonly used for small consumer systems where low light level are needed and the system is switched on and off frequently, which can be achieved in an efficient way with UV LEDs.

**Radiant intensity:** The amount of usable light produced by a UV-C lamp in a defined spectrum per unit of surface area. Generally expressed as $W/m^2$ or $mW/cm^2$.

**Radiant flux:** The total amount of usable light produced by a UV-C lamp in a defined spectrum and unit. Generally expressed as W or mW.

**Radiant efficiency:** The amount of useable and defined UV-C light produced in % from the measured input power.

## 2.3 UV ballasts or lamp drivers

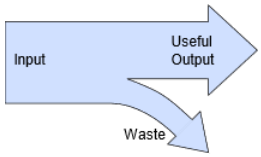
UV lamp drivers or ballasts are used to start and operate UV lamps. There are two types of ballast commonly used; Magnetic ballasts and electronic ballasts or lamp drivers.

**Magnetic ballast**: A magnetic ballast consists of a core and coil assembly to perform the minimum functions necessary to start and operate an UV lamp. The efficiency and power factor of magnetic ballasts is lower than that of electronic lamp drivers. They operate at mains frequency (usually 50 or 60Hz) resulting in flickering and reduced disinfection efficacy and shorter lamp life.

**Electronic ballast or lamp driver:** An electronic ballast or lamp driver consists of electronic components to convert the input voltage to the high frequency (>20kHz) output voltage to start and operate an UV lamp. Electronic lamp drivers have a higher efficiency, higher PF and low THD resulting in lower energy costs and reducing environmental impact. Moreover due to high frequency operation, lamps can be operate more reliably, last longer, are quiet and can be dimmed. Electronic lamp driver give more flexibility to establish various input/output configurations to accommodate a wide range of lamps. Furthermore, intelligent electronic drivers can communicate through modbus or other serial protocol to monitor driver temperature, lamp voltage etc. for maintenance purposes.

**Efficiency(η):** The ratio of output power and the input power expressed as a percentage. The difference between the input power and the output power is the wasted dissipated energy and is converted into heat, resulting in a higher temperature of the lamp driver or ballast. Modern lamp drivers have a target efficiency of more than 95%.

Efficiency (η) formula: $\eta = \frac{P_{out}}{P_{in}} \cdot 100\%$




**Power Factor (PF):** Power factor is the ratio between useful (true) power (W) to the total (apparent) power (VA) consumed by an electical device. In fact it defines how in phase the input current and voltage is.
The power factor can range from 0 to 1. A Power factor of 1 means that current and voltage are perfect in phase. Modern lamp drivers have a target Power Factor of more than 0.98.

Power Factor (PF) formula: $PF = \cos\cos \emptyset = \frac{Active\ Power\ (W)}{Apparent\ Power\ (VA)}$

A power factor correction (PFC) circuit is added to a power supply or lamp driver circuit to bring its power factor close to 1.0 and reduce harmonics.

**Total Harmonic Distortion (THDc) current:** The Total Harmonic Distortion (current), or THDc, of a signal is a measurement of the harmonic current distortion present and is defined as the ratio of the sum of the of all harmonic current components (n=2 tot ) to the fundamental current frequency ($I_1$). THD is used to characterize the power quality of electric power systems.
A high THD results in higher power losses in the power grid due to the presence of high current harmonics. THD is regulated according to standard IEC61000-3-2.

Total Harmonic Distortion (THDc) current formula: $THDc = \frac{\sqrt{I_2^2+I_3^2+I_4^2 \ldots I_n^2}}{I_1} \cdot 100\%$

**Lamp Cable:** Cable between the ballast (or lamp driver) and lamp. As indicated above, high frequency lamp drivers offers several advantages over operation on EM ballasts. To maintain these advantages when a large distance between lamp and driver is required, some attention has to be paid to the lamp cable. Cable properties that can degrade performance at high frequencies are capacitance, inductance, series resistance and dielectric losses. Selecting the right cable optimizes the performance of the UV disinfection system.

## 2.4 Controllers

**1-10V dimming control:** Dimming control with a 1 to 10Vdc signal to control the light intensity of a lamp.

**Modbus control:** Modbus is a serial communication protocol developed by Modicon for use with its programmable logic controllers (PLCs). In simple terms, it is a method used for transmitting information over serial lines between electronic devices.

## 2.5 UV system selection parameters

**Validation:** A test or process executed by a independent third party aiming to give claimed effects a repeatable and precise scientific foundation.

- To prove scientifically that something does what it claims to do, an validation test report is available;
- For instance: USEPA validation.

**Certification:** A test or process executed by a independent third party aiming to give claimed effects a repeatable and precise scientific foundation.

- .To prove scientifically that something does what it claims to do, an validation test report is available and a certificate available as proof a positive test result;
- For instance: DVGW or ÖNORM certification, CE or UL/cULcertification.

**TCO (Total Cost of Ownership):** Total lifecycle-cost of a product or application expressed as all cumulative costs and consumptions of that product over its service life divided by the amount of product treated. For instance €/$m^3$ of water treated. When done methodologically sound this serves as an excellent comparative value.

**Energy consumption:** Actual, from the wall, energy consumed by a process in its entirety over a set normalised used timeframe and constraint expressed as Watts of kilowatt hours (kWh).

# 3: Application of UV-C in water treatment

## 3.1 UV-C Water treatment processes

A UV-C water treatment process may consist of one or more steps, including a UV-C treatment step. UV-C water treatment has a measurable and repeatable impact on water quality and usability. In general, water treatment aims to improve water quality to a defined, beneficial level. UV-C treatment can be applied in various water treatment processes.

**Centralised:** A water treatment facility that collects water from a multitude of sources, collecting and treating it centrally, generally owned and operated by a consortium or a community.

**Decentralised:** A water treatment facility that collects water from a single or multitude of sources, generally owned and operated by a single owner or stakeholder.

**Waste water:** Water produced as waste from a process or community, often significant worse in quality as before use. Sewage for instance is considered wastewater. Waste water often contains valuable nutrient and component for up-cycling or valorisation.

**Process water:** Water used in industrial processes, often chemically close to drinking water in quality but because of the way it is used on a site it is not deemed fit for consumption like drinking water is. Sometimes process water is of much higher chemical quality than drinking water when RO or demi-wateer are used, conversely sometimes process water is untreated groundwater and of much lower quality than drinking water.

**(Ultra) pure water:** An industrial grade of water significantly higher is chemical quality than drinking water. In general (ultra) pure water is expected to have near-zero measurable contaminants and is produced with advanced treatment methods like reverse-osmosis, (electro) de-ionisation and adsorption. Demineralised (demi) water is a common form of ultrapure water

**Drinking water:** Water supplied by a governmental or semi-governmental company officially validated and guaranteed to be of drinkable quality. In most cases only drinking water companies can provide drinking water and “drinking water” is an official formalised quality and quantity.

## 3.2 Water quality

Water quality expressed by its general fitness for use and consumption. In general this is a defined combination of biological, chemical and ecological safety. UV-C treatment can be used to improve water quality on a biological, chemical and ecological level.

**Biological Water Quality**

Refers to water quality based on its content of living organisms and genetic material (DNA/RNA), typically single-celled microorganisms such as viruses, bacteria, algae, and yeasts. High biological water quality often involves the absence of pathogens—organisms that can cause illness—achieved through disinfection or reducing nutrients that support microbial growth.

A commonly used metric for biological water quality in relation to UV technology is Log Reduction of Microorganism. Log measures the decrease in microbial concentration, often expressed as a log scale (e.g., 3-log reduction means 99.9% of microorganisms are inactivated). Common microorganisms used for testing include E. coli, Cryptosporidium, Giardia, and pathogenic viruses.

**Chemical Water Quality**

Describes water quality based on its concentration of dissolved chemical substances. These include inorganic salts like common table salt and hardness salts, as well as potentially harmful

substances like heavy metals, pesticides, hormones, pharmaceuticals, and industrial chemicals. Maintaining chemical water quality means minimizing the presence of toxic or undesirable components.

A commonly used metric for Chemical water quality is the concentration of target contaminants. This measures the reduction in concentration (e.g., in milligrams per liter (mg/L) or micrograms per liter (µg/L)) of specific chemical pollutants, such as:

- Pesticides (e.g., atrazine, glyphosate)
- Pharmaceuticals (e.g., antibiotics, painkillers)
- Hormones (e.g., estrogen, testosterone)
- Industrial Chemicals (e.g., phenols, dioxins)
- Disinfection Byproducts (DBPs) (e.g., chloramines, trihalomethanes).

Total Organic Carbon (TOC) is another metric to indicate chemical water quality. This represents the amount of carbon in organic molecules within the water. UV technology, often combined with AOPs, helps break down complex organic molecules, reducing TOC.

**Ecological Water Quality**
Focuses on water quality in relation to its impact on ecosystems. This includes living organisms in the water, the surrounding environment, and broader biodiversity. Poor ecological water quality can lead to harmful effects on health, ecosystem stability, and the long-term reusability of water resources. It also considers more subtle, long-term impacts on ecological balance and sustainability.

## 3.3 UV-C disinfection for water challenges

**C**urrent societal and environmental issues can be addressed through water research, water technology, or raising awareness. If left unaddressed, these challenges are expected to have a measurable negative impact on society, the environment, or public health. UV-C technology offers solutions to a variety of water-related challenges.

**AMR (Antimicrobial/Antibiotic Resistance):** The increase in resistance to medicines, antibiotics in particular, of human disease causing microbiology (pathogens). The WHO predicts that the increase of antibiotic resistance and resistant organisms is the most important risk for global health for the future. UV-C disinfection is designated as one of the most promising and effective technologies in mediating this challenge.

**Infection pressure:** The increase of risk and proliferation of infections and infection causing pathogens. From one side from growing resistance to antibiotics and biocides, from the other side to increased biological risk from overpopulation, gentrification and zoonosis. The increase of infection pressure combined with the closely related AMR challenges pose a significant risk to the global future where UV-C disinfection can pose a pivotal technology in it's (chemical free and efficient) mediation.

**Chlorine resistance:** The increase in resistance to chlorine of microorganisms in drinking and swimming water caused by the chlorine added to is as a biocide. Chlorine resistance corresponds in mechanism and to some extent with AMR, escalating it's risk and impact. UV-C is an efficient and sustainable alternative for chlorine use as a biocide that does not exhibit these resistance traits.

**Chemical free/lean:** The general aim and desire for industry and consumer products to use less and less harmful chemical components or processes. UV-C technology can be an alternative to biocides and chemical disinfectants playing an important role in decreasing chemical use and consumption, also UV-C technology can remove chemicals used in these processes. In some

cases completely chemical free operation or production are less sustainable or safe so the preferred and more favourable term is chemical-lean.

**Legionella control:** A technology or process that aims to avoid and control Legionella contamination of (warm) water systems. Legionella is a pathogen that can cause potentially deadly Legionnaires' disease and is often controlled by UV-C application.

# 4: Appendix: Units

These units are generally accepted or defined to be used as quantifiers for the terms given in this document. Where possible these or directly related SI units should be used.

- **Radiant intensity:** mW/Cm$^2$, W/m$^2$
- **Radiant flux:** mJ/Cm$^2$, J/m$^2$
- **Radiant efficiency:** %
- **UV-C-dose**: mJ/cm$^2$, J/m$^2$
- **Transmittance:** % (T2/10/50/100 @254nm)
- **Wavelength;** nm (nano metrer)
- **Current:** A (Ampere)
- **Voltage:** V (Voltage)
- **Frequency:** Hz (Hertz)