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ULTRAVIOLET (UV) LIGHT FACT SHEET

TREATMENT OF RESIDENTIAL DRINKING WATER USING UV

Ultraviolet light has many uses. Some people tan their bodies under ultraviolet light. Dentists use ultraviolet light to cure certain types of polymers used in dental procedures. Parasites, bacteria and viruses can be inactivated to make water safe to drink and organic contaminants can be oxidized. For the purposes of this article, the focus will be on residential drinking water treatment devices using ultraviolet light technology.

What is Ultraviolet Light?

Ultraviolet light (UV), as early as 1845, was known to influence microorganisms. Since then, disinfection of drinking water using UV has become a staple process around the world.

Light waves are a form of electromagnetic energy. The measurement unit of wavelength used to describe light waves is called a nanometer (nm). A nanometer is 1/1,000,000,000 of a meter. Visible light wavelengths fall in the range of 400 – 700 nm. Infrared heat lamps produce relatively long wavelengths in the range of 700-1000 nm. UV light can be broken down into UVA, UVB, UVC and Vacuum UV. UVA, which are the tanning rays of the sun, fall in the range of 315 – 400 nm. UVB, which are the burning rays of the sun, fall in the range of 280 – 315 nm. UVC, which are the cancer causing rays of the sun, fall in the range of 200 – 280 nm. Finally, there is vacuum UV which falls within the range of 100 – 200 nm.

Waterborne Infectious Diseases and Inactivation

Our bodies' immune systems are amazing and can handle virtually any pathogen encountered but when an ingested organism propagates millions or billions of copies of its self, our immune systems become overwhelmed and we get sick. Waterborne infectious disease can be broken down into four broad organism categories: Virus, bacteria, parasite and protozoa. Some common waterborne illnesses caused by these organisms include: Hepatitis A; Dysentery; Schistosomiasis and Cryptosporidiosis.

Every infectious organism's cell(s) contain specific instructions for replication. These sets of instructions are called DNA and RNA. DNA tells cells what to do. These instructions are written in a language called the genetic code. Like any set of instructions, the instructions must be in the right order. Exposure to UVC light can affect the instructions by degrading or removing sections of the code. It is fascinating to note that that DNA and RNA absorb UVC light energy very well at 254 nm. This absorption characteristic combined with UVC light of the proper energy (intensity) can render infectious organisms harmless by eliminating their ability to reproduce. This process is called inactivation. It is called inactivation because in most cases, the organism is not killed. It is simply rendered incapable of replication.

The Hardware

The heart of any UV system is its lamp. There are many types of UV lamps with varying characteristics but in the interest of keeping things simple, this discussion will be limited to low pressure (LPUV) lamp technology. A typical LPUV lamp is similar in construction to fluorescent lights we see in offices and homes every day. The LPUV lamp tube is made of quartz-based glass and contains a small amount of mercury. At either end, there is a tungsten electrode. When electricity is applied to the electrodes the mercury vaporizes and the lamp emits heat and light. A low-pressure UV lamp has a relatively low internal pressure and it is considered a monochromatic lamp because it radiates UV light centered around one wavelength: 254 nm. Note that this just happens to be the same wavelength that is readily absorbed by DNA and RNA as mentioned in the previous section.

The LPUV lamp is isolated from contact with the water by a device called a sleeve or thimble depending on the design of the UV chamber. A sleeve is open at both ends and a thimble is closed at one end much like a large test tube. Like the lamp, the sleeve or thimble is constructed out of glass made from quartz. Quartz is more transparent to UV light than silica based glass.

The sleeve/thimble and lamp assembly is then housed in either a polymeric or stainless steel chamber. This chamber, sometimes called the reaction chamber, is where the water is routed to become disinfected by the UV light. Often, during the design stages, this chamber undergoes computational fluid dynamics (CFD) modeling as a first step to ensure proper UV light distribution throughout the reaction chamber. Validation of the reaction chamber is an essential design requirement.

The quartz sleeve/thimble assembly can be prone to fouling. Fouling is an accumulation of dissolved solids often found in the water. The products that can accumulate are calcium, iron and manganese that have photocatalytically reacted with the UV light to form a film or scale on the quartz surface This is why it is important to install a UV system post-softener whenever possible. In some cases to help minimize premature fouling, a manual or automatic quartz wiper system is part of the design. The wiper system consists of a carriage that houses rings that fit tightly around the quartz sleeve and act as a “windshield wiper” of sorts that moves back and forth along the length of the sleeve periodically or on an as-needed basis.

Certification/validation standards typically require an electronic means to monitor the UV lamp performance to ensure adequate disinfection is occurring. This monitor is calibrated to a known value and then it monitors the output of UV energy. Depending on the sophistication of the UV system, if the monitor detects inadequate amount of light reaching the water inside the reaction chamber the system can trigger one or any combination of the following events: a wiper cleaning cycle; an alarm- either audible or visual; a shutdown of the UV lamps; a shut off of water flow through the system; an automatic ramp-up of power applied to the lamp and an email or text message indicating the need for immediate attention or maintenance.

UV Dose

UV light can inactivate waterborne infectious organisms but there is an important detail to understand: That is the concept of UV dose. UV dose is a calculation that consists of three variables:

- The speed of the fluid moving past the lamps. This speaks to “contact time”
- The transparency of the fluid to UV light (transmittance). This is called UVT or T10
- The power of the UV light emitting from the lamp expressed in Wm^2

Dose is a function of applied energy (Joule) per given area (square centimeter). Dose is typically expressed as mJ/cm^2 (J/m^2). It is critical to expose the waterborne infectious organism to the proper UV dose because different organisms require different doses to become inactivated. If the proper UV dose is not applied, there is a possibility that the organism could remain viable and potentially cause disease. The higher the dose, the higher the certainty of inactivation.

Certifications

While there are many certification programs around the world, the important one to note for residential drinking water applications in the North America is NSF/ANSI 55. There are two types of systems tested for and certified within the NSF/ANSI 55standard:

Class A systems (minimum dose of 40 mJ/cm^2) are designed for use on drinking water of unknown quality to disinfect and/or inactivate microorganisms, including bacteria and viruses, from contaminated water to a safe level. Class A systems may claim to disinfect water that may be contaminated with pathogenic bacteria, viruses, Cryptosporidium or Giardia. Class A systems must include alarms and a UV sensor to assure proper dosing and treatment.

Class B systems (dose of 16 mJ/cm2) are designed for supplemental bactericidal treatment of public or other drinking water that has been deemed acceptable by a local health agency. Class B systems may claim to reduce normally occurring nuisance microorganisms.

Interferences of the UV Disinfection Process

As mentioned previously, a certain dose of UV light must reach the organism in order for it to be inactivated, however, it is important to understand that there are things that can interfere with the UV light and prevent it from reaching the target organism. First on the list is turbidity. Measured in NTUs, turbidity is caused by small particles or colloidal material suspended in the water. These particles block, shadow and absorb the UV energy. Keep in mind that the largest viruses are about 200nm in size and a typical grain of sand is around 1mm. Using simple math, we can calculate that approximately 5,000 viruses can hide behind a grain of sand! Next on the list are chemicals and compounds in solution in the water that can absorb UV light. Common chemicals and compounds that can be present in the water are: humic and fluvic acids, metals, nitrates, sulfites and sequestering agents like poly-orthophosphates. Another interference can be fouling of the quartz sleeve. Metals in solution in the water can photo-react with the UV light and deposit a thin film or scale on the quartz sleeve housing the UV lamp and lower its apparent output. Water that looks crystal clear to the naked eye can actually have very low UV transmission characteristics and this is why it is imperative that the water is tested for UVT % before selecting a system for any given application. Finally another common interference is simply the UV lamp ageing. Expected useful lamp life for a low pressure UV lamp is approximately 10,000 hours. As the lamp ages, its performance diminishes and its ability to output the proper UV energy reaches an end. Finally a process called solarization of the quartz sleeve can cause interference. Over time, the UV light can cause the quartz sleeve to become less transparent. Although the frequency of replacement varies by manufacturer, typically the sleeve is replaced proactively every 3-5 years.

Best Practices

Considering the fact that UV is applied as a disinfection step in drinking water applications, it is critical that the health and well-being of the customer is foremost in the mind of the person selecting and installing the system.   The first step is to have a clear understanding of the application by asking important questions and having a full water test done.

- Is the water from a municipal or private source?
- What is the organism of concern?
- Does the water contain chlorine or chloramine?
- Is the water source ground or surface water?
- What is the highest GPM flowrate the UV unit will see at any given time?
- What is the hardness of the water?
- Are there any metals present in the water?
- What is the UVT of the water?
- Is an NSF/ANSI 55 Class A or Class B system required?

Once these questions are answered, the proper pretreatment (if needed) can be determined and the proper size of the UV system selected. It only through these steps can a water professional be confident that their customer will be protected from waterborne infectious disease because the UV system is working as it should.

The environment is of the utmost concern of many people today and with this in mind, it is important to follow all local, state and federal regulations when disposing of used UV lamps. In many communities there is a program for the disposal of florescent lamps and this would be an appropriate method for the disposal of UV lamps. In the case of a lack of such a program, it is highly recommended that the UV system manufacturer is contacted for advice for the proper disposal of the lamp.

As always, all manufacturer recommendations for application criteria, installation, safety precautions and maintenance should be followed to ensure the warranty remains in effect, the system performance is maximized and the safety of the user and installer is preserved. Also, all applicable local, state and national codes should be followed to ensure the system is properly sized and installed.

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