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Industrial Water Purification

MAINTAINING A STERILE HIGH PURITY WATER SYSTEM

Introduction

Maintaining a microbe free deionized water system is like trying to maintain a vacuum, and nature abhors a vacuum. Microbial contamination in a "Microbe Free" water supply can, and will come from any design or maintenance flaw in the system. It is one of the more graphic examples of Murphy's Law: "If anything can contaminate a water system, it will."

Various kinds of microscopic life can contaminate a water system. The most common are bacteria, algae, and molds. Treatments for all are similar.

Biological Control in industry

Microbial Kill

Ultraviolet radiation, or ozonation are typically used to kill algae and bacteria in high purity water systems.

Sub-Micron Filtration

Live and dead bacteria can be removed by sub micron cartridge filtration, membrane ultra-filtration, or membrane nano-filtration. Relying on filtration for biological control is perilous because filters that have trapped live bacteria can become breeders. Sub micron cartridge filtration should be used in conjunction with one or more active sterilization steps.

Water Flow Velocity

Under the theory that an ounce of prevention is worth a pound of cure, maintaining a flow rate of 4.5 fps (feet per second) or greater to high purity water piping will prevent bacteria and other biomass from adhering to internal surfaces. Because flow rates to production processes are often variable, a pump and recirculation loop are often added to maintain the needed flow rate. Water is then drawn off the high purity water loop using short drops to use points.

Periodic System Sterilization

Occasionally a comprehensive system sterilization using oxidizers or heat is required to keep a pure water system biologically clean.

Sources of Biological Contamination

Mixed Bed Deionizer Resin

The very devices that make the water pure are one of the major potential contributors of bacterial contamination. The ion exchange resin in mixed bed deionizers, besides making very high purity water, is also an excellent growth medium for bacteria. There are

procedures and techniques that can be used in the handling of mixed bed deionizers that will mitigate biological contamination, but additional equipment such as UV sterilizers are still needed down stream of the mixed beds for microbial control.

Dead ends

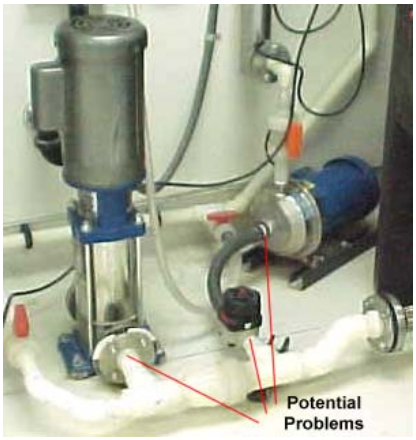
Dead ends are the most frequent contributors of bacterial contamination to an otherwise bacteria free system. A dead end is a branch off a main deionized water line that is not used and is where bacteria can hide during sterilization. A dead end can be an unused line, a capped or plugged tee, an empty filter housing or any other place where water does not flow. A dead end is defined as any branch off a water line that is more than three pipe diameters from the line.

All dead ends must be eliminated. When a dead end is found, it should be cut out and replaced with straight pipe.

Open Vents

All water storage tanks must be vented. As the water level in a storage tank rises and falls, the tank must be allowed to "breathe" to prevent the tank from bursting or imploding. Tank vents must have filters to prevent airborne contaminants from entering the tank.
Vent filters can be anything from 0.10-micron hydrophobic cartridges to standard 1-micron filters. The choice of filter depends on the dollars to be spent and how critical the application is. The only thing certain is that a vent filter is a necessity.

Leaks



Leaks in plumbing can compromise a sterile system. Especially troublesome are leaks on piping leading to the suction side of pumps. Air or any other fluid around the leak can be a vector for biological contamination, which can be pulled into an otherwise sterile system by the suction of a pump.

But no matter where they are, all leaks are potential sources of contamination and should be detected and repaired.

Storage Tank and Piping Sterilization

Even with effective bacterial control, periodic system sterilization is still necessary to assure a clean system.

Sterilization of a deionized water system consists of four basic steps:

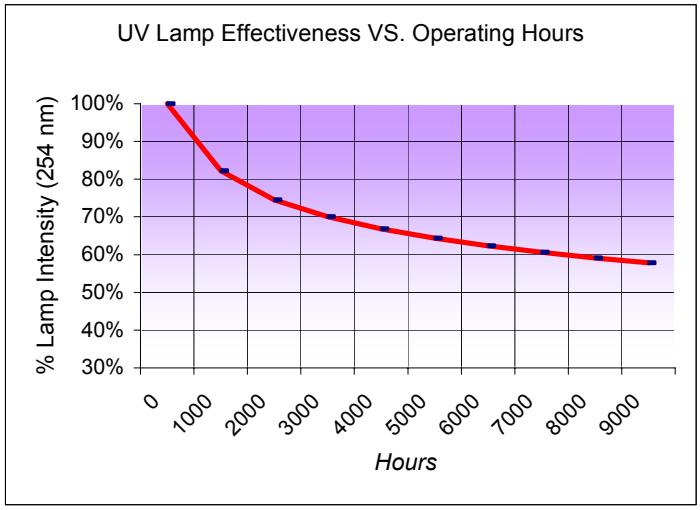
1. Inspection and Repair.
2. Preparation of the system for sterilization
3. Chemical/Heat Sterilization and Rinsing.
4. Post Sterilization Maintenance.

Inspection and Repair
Before beginning chemical sterilization, the tank and the entire water system should be inspected for design and installation flaws. An improperly designed or poorly installed water system can be sterilized one day only to have it re contaminated the next. Repeated sterilizing will have little effect. Only after the hardware has been checked out and any design flaw or material defects corrected, should the actual chemical sterilization be attempted.

Ineffective Ultraviolet Sterilizers
The installation of UV sterilizers should be checked to assure that they are not trapping air. If the UV sterilizers are mounted horizontally, the outlet connection should always be upward. Sterilizers mounted vertically should have the water flowing from bottom inlet to top outlet.

Most UV lamps have 9,000-hour ratings and should be replaced at least yearly.

> Note: Even if a UV lamp glowing, there is no guarantee that it is producing the correct wavelength UV radiation to kill microorganisms.



Make sure that all UV sterilizers are properly sized for the flow rate and that the water being fed to the sterilizer is clear. UV radiation will not pass through cloudy or aerated water. Ideally, water to be sterilized should be filtered prior to the UV sterilizer. The same holds true for dirty quartz sleeves. If the quartz sleeves containing the UV lamps are dirty, the UV light will be inhibited from providing the designed maximum kill.

Preparation of the system for sterilization
Bypass Deionizers
System deionizers must be disconnected and replaced with bypass loops to prevent the sterilant from harming the ion exchange resin. The resin in the deionizers is as susceptible to destruction by a sterilant as the microorganisms.

Turn off UV Sterilizers
The radiation from UV sterilizers will reduce oxidizers, rendering them ineffective. All UV sterilizers should be turned off during a system sterilization using chlorine, hydrogen peroxide or other oxidizer.

Remove Cartridge Filters
All used disposable cartridge filters in a system to be sterilized should be removed and discarded before beginning a sterilization procedure. Any dirt or silt deposits on used filter cartridges can harbor microorganisms that could compromise disinfection.

While it is theoretically beneficial to replace disposable cartridges with new cartridges at the beginning of sterilization

(so that the cartridges are also sterilized), it is rarely practical. Chemicals used in sterilization can damage cartridge filters. Also, sterilization of a highly contaminated system can dislodge significant amounts of filterable material that will clog any filter left in the system.

This problem becomes especially significant if the sterilant solution is to be recirculated. Cartridge filters left in place can clog during a recirculated sterilization, restricting the flow and interfere with the entire sterilization process. In most application, disposable cartridge filters should be replaced after sterilization.

Chemical/Heat sterilization and rinsing

Sterilizing a water system generally consists of filling the system with either high temperature water, or more commonly, a high concentration of oxidizer.

Heat Sterilization

Heat sterilizing a high purity water system consists heating the water in the system to 160+ F or more, and maintaining the temperature for a minimum of an hour. Heat sterilization is most applicable to stainless steel and glass pipe. Heat sterilization is not recommended for most plastic pipes, especially PVC.

Chemical Sterilization and Rinsing

The sterilizing solution can either stand in the pipe or recirculate for four to seventy-two hours. Effective oxidizer concentrations can vary from 50 to 1,000 ppm, depending on the oxidizer, contact time and the total amount of contamination present.
No matter what the sterilant or its concentration, the longer the contact time, the better.

The most common sterilizing oxidizers are:

- Chlorine
- Hydrogen Peroxide
- Peracetic Acid
- "Renalin" or "Minncare", (A combination of Peracetic Acid and Hydrogen Peroxide)

Whichever sterilant is used, it should be added at the furthest point up stream of the water purification system as is practical. The solution should be allowed a residence time of a minimum of four hours. The best time to sterilize a system is over a weekend, which will allow a contact time of about sixty hours. The sterilization solution can be introduced to the system on a Friday night and rinsed out Monday morning, allowing the weekend for maximum bacterial kill.

Example Sterilization Steps

- ✓ Disconnect the deionizers and install bypass loops.
- ✓ Turn UV sterilizers off.
- ✓ Load a solution feeder storage tank with an oxidizer. (In this example chlorine is the oxidizer. Chlorine is useful because it is cost effective, a strong oxidizer and because of the ease of detection. The human nose can detect chlorine concentrations to below 0.5 ppm.)
- ✓ Tag all the outlets with signs indicating that a sterilization procedure is underway.
- ✓ Turn on the DI water recirculation pump.
- ✓ Turn on the feeder and charge the deionized water distribution piping with chlorinated water, ~~ 200 ppm.
- ✓ Once the feeder is feeding, one by one, open each deionized water outlet until the oxidizer is detected and then close the outlet.
- ✓ Once all outlets are checked and closed, system sterilization is under way. The sterilizing solution should be allowed to recirculate or stand in the deionized water piping for a minimum of four hours with twenty-four hours as an optimum.
- ✓ Drain the system and rinse with deionized water by opening all the deionized water outlets and allowing them to run for approximately five minutes.
- ✓ Turn UV sterilizers on.
- ✓ Open all deionized water outlets one by one, and check each deionized water outlet at full flow rate until no trace of oxidizer can be detected and acceptable water purity is being obtained, and then close the outlet.

Once all outlets have been checked and closed, system sterilization is complete.

Example Sterilization Check List

[ ] Deionizers Disconnected and replaced with bypass loops
[ ] UV Sterilizers switched off
[ ] Solution feeder storage tank loaded with (12.5%) Chlorine
[ ] Feeder On Time:_____
[ ] Deionized Water Outlets Opened - Chlorine Residual_____ppm
[ ] Feeder Off Time:_____
[ ] Chlorine Residence Time_____
[ ] UV Sterilizers switched on
[ ] Deionized Water Outlets Purged Time:_____
Oxidizer Residual_____ppm
Next Plate Count_____Date_____

Post-Sterilization and Operating System Maintenance

Routine maintenance is critical in maintaining a clean system. The following are some of the maintenance procedures recommended:

- ✓ The area around the storage tank should be kept clean and neat.
- ✓ All filters should be routinely inspected and changed when pressure drops exceed manufacturers recommendations, usually a five-pound drop.
- ✓ Ultraviolet sterilizer lamps should be replaced every six to nine months.
- ✓ Any proposed plumbing changes should receive management attention to reduce the possibility of introducing dead ends into the system.

- ✓ Bacterial sampling should be done periodically to determine microorganism activity in the system. A colony count cutoff point should be established to trigger automatic system sterilization.

Ultraviolet Sterilizers

Ultraviolet radiation is used primarily to kill any microorganisms present. The subject water is exposed to electromagnetic radiation of a wavelength of 2537 angstroms. The quantity of radiation normally recommended for killing most bacteria, viruses, fungi and other microorganisms is 30,000 to 40,000 micro watts seconds per square centimeter per second.

The variables associated with UV are flow rate, water clarity, tube clarity and the quantity of the proper wavelength radiation available.

For UV systems to work, the lamps must be replaced at least once a year. If the lamps are not replaced regularly the UV system will become just another piece of pipe and will do absolutely nothing.

UV Servicing:

1. Replace ultraviolet lamps every 6 to 9 months of continuous use, or when the monitor reads 70% of the new lamp output.
2. Disinfect the entire system after shutdown or servicing.
3. If equipped, operate the quartz jacket wiper system regularly on manual models (push/pull stroke). You cannot over clean the quartz jacket(s).
4. Keep a record of ultraviolet lamp replacement dates, and lamp UV intensity readings if the sterilizer is equipped with a meter.
5. Test the water quality periodically. Send samples in bacteria free bottles, giving the time and date drawn, to a licensed testing laboratory. The lab should maintain a log showing the results of all completed tests.
6. During UV lamp replacement, clean inside and outside of the quartz jacket(s) with denatured alcohol. Clean and polish the inside of the radiation chamber. Clean the lens on the fail-safe monitor sensor. If purifier is supplied with a wiper cleaning system, replace the wiper rings and the quartz O-ring.

For more information on UV, please see "Ultraviolet (UV) Sterilization - Fact Sheet"