Peracetic Acid as an Alternative Disinfectant

by Jacquelyn N. Wilson

Throughout the world, the most commonly utilized wastewater disinfectant is chlorine, usually added as sodium or calcium hypochlorite, with use of a dechlorination method. Chlorine is a persistent disinfectant, which does not degrade in the environment and so must be quenched, typically with sodium bisulfite, in order to meet effluent permit requirements. The wide span use of this product is primarily due to its inexpensiveness and accessibility. However, recent health concerns have emerged regarding the harmful by-products produced by chlorination. In surface waters pretreated with high doses of chlorine, formation of total organic halides are produced which show long-term toxic risks.

In order to reduce disinfection by-products (DBPs) formation, alternatives to disinfection treatment have gained momentous traction in the water and wastewater industries. Combinations of commonly used disinfectants, such as ultraviolet (UV) and chlorine, have been pursued as viable options for reducing total organic halide concentrations. Additional research has been performed to find an alternative disinfectant similar to chlorine that does not produce harmful by-products – in other words, peracetic acid.

Background of PAA

Peracetic acid, or peroxyacetic acid (PAA), is an aqueous equilibrium solution of acetic acid, hydrogen peroxide and water. The equilibrium is represented in Figure 1. PAA has been used in the food and beverage and paper industries for many years and has been studied in wastewater disinfection since the 1980s. Peracetic acid’s direct oxidation and destruction of the cell wall of microbial pathogens allows for its prime candidacy as a disinfectant in wastewater treatment.

Figure 1. Peracetic Acid Equilibrium

Peracetic acid (peroxyacetic acid) exists in an equilibrium between acetic acid, hydrogen peroxide and water. Courtesy of PERAGreen Solutions, LLC

Peracetic acid has a diverse repertoire of uses including: disinfection of secondary systems, disinfection of combined sewer overflow (CSO) and sanitary sewer overflow (SSO) systems, filter cleaning, algal and snail fouling, and bypass/redirect/blend system disinfection. The product is dependent upon contact time, mixing and starting dose. Peracetic acid has been seen to be relatively insensitive toward suspended solids when provided enough contact time, thus making it a prime candidate for CSO disinfection. However, the best results for PAA disinfection can be seen after filtered tertiary effluents.

Properties

The PAA product is a colorless, clear liquid with no foaming capabilities. A strong vinegar odor is observed due to the acetic acid concentration, and the odor is more pungent with increasing concentration strength. The pH is less than 2 with a specific gravity of 1.10 to 1.11, depending on temperature. The freezing point of the product is 40.3°C. The product is produced by reacting acetic acid and hydrogen peroxide over a few days in order to achieve high yields. Commercially, this product is available in concentrations from 2 to 15 percent weight/weight. Though peroxide is also a commonly recognized disinfectant, the active disinfecting agent within this equilibrium – PAA – is highly active at low concentrations across a wide range of microorganisms.

The germicidal properties of PAA are found to be bactericidal at 0.001 percent; fungicidal at 0.003 percent; and, sporicidal at 0.3 percent. The disinfection efficacy of PAA on microorganisms can be ranked as: bacteria>viruses>bacterial spores>protozoan cysts. Its bactericidal effectiveness is dependent upon the organism. A specific fecal coliform bacterium, E. coli, has been found to show low resistance to the PAA mechanism, and similarly fecal coliform in general. Following in susceptibility to PAA disinfection are enterococcus (fecal bacterium), giardia (protozoan parasite) and cryptosporidium (microscopic parasite).

Disinfection by-product formation during PAA disinfection has been studied and found that no brominated or chlorinated phenols are formed. The peracetic acid decomposition products are acetic acid, hydrogen peroxide, oxygen and water. Peracetic acid can be consumed in an aqueous solution in three ways: spontaneous decomposition, hydrolysis and transition-metal-catalyzed decomposition. High levels of solids in the water system can also consume PAA, so adequate dosage and contact time is required for disinfection. Within the pH range of 5.5 to 8.2, spontaneous decomposition of PAA to acetic acid and oxygen occurs. Peracetic acid produces little to no toxic or mutagenic by-products after reaction with organic material in wastewater effluents or surface waters. By-products produced are mainly carboxylic acids, which are not recognized as mutagenic. No halogen disinfection by-products have been observed.

Mechanism

Similar to chlorine, PAA is an oxidizing agent. It oxidizes the outer cell membrane of bacterial cells by disrupting the function of the lipoprotein cytoplasmic membrane and the transport through cell walls. Oxidations occur by the transfer of electrons – the stronger the oxidizer, the faster the electrons are transferred to the microorganism and the faster the microorganism is inactivated or killed. Peracetic acid has the second highest oxidation potential, next to ozone, among common disinfectants as shown in Figure 2.

Figure 2. Oxidation Potentials of Bicidal Agents

Common disinfectants utilize oxidation methods for pathogen inactivation. The stronger the oxidant, the faster the inactivation.

Peracetic acid reacts with organic matter in sewage water systems. The greater the amount of organics, the longer the reaction time required for disinfection. In systems with little organic...
matter, holding times of less than 10 minutes are functional for disinfection. Highly organic systems require up to 30 minutes or greater, depending on the system.

Applications
Peracetic acid is commonly used as a disinfectant in the food, beverage and paper industries and has begun gaining traction in wastewater and water treatment. Studies of PAA have been performed globally and are cropping up in North America at an increasing rate. North America now has several active PAA applications at wastewater facilities. The product is being used as a tertiary disinfectant, CSO disinfectant, blend/bypass/redirect disinfectant, enhancing UV disinfection, and lagoon disinfectant (Figure 3).

In secondary systems, PAA has been seen to outperform chlorine and bisulfite applications in pathogen reduction as well as cost. Research had previously suggested that PAA was too expensive to produce due to limited production globally, however, studies show that product feed is so low to achieve kill that a 26 percent cost reduction is possible when compared with chlorination/dechlorination. Typical feed rates for secondary systems are found to be below 1.0 ppm. In order to achieve maximum pathogen reduction, a residual floor of 0.35-0.40 ppm must be maintained as seen in Figure 4. A hand-held DPD test using a total chlorine colorimeter can be used to monitor residual and establish control.

Figure 3. Largo Wastewater Treatment Plant in Florida. A peracetic acid pilot study was performed at the Largo WWTP in Florida. The facility looks to use PAA as a disinfectant in the future.
Systems feeding PAA have seen tremendous success and versatility in the use of the product. Peracetic acid has been shown to bring plants into compliance within a half-hour of feeding, reduce pathogen levels by 25 percent within five seconds and handle pathogen spikes up to 290,000 CFU/100 mL without changing dosage. To increase pathogen kill, a combination of UV and PAA disinfectants can be utilized. This is known as an advanced oxidation process that occurs as the UV light enhances the formation of radicals such as hydroxyl groups, found in PAA, making the environment unfavorable to the survivability of the microbes. Peracetic acid naturally decomposes and at effluent discharges, PAA residuals decrease in concentration by 94 percent eight feet into the receiving stream from the outfall point from 0.39 ppm in the effluent overflow to 0.02 ppm.

In CSO and lagoon applications, the increase organic material and solids levels can increase the starting dosage required as well as the contact time needed for treatment. Solids levels and PAA dosage can be seen to follow a straight line curve as shown in Figure 5. As the total suspended solids and volatile suspended solids (TSS/VSS) levels increase, so too does the feeding dose of PAA increase. The product requires increased time to penetrate the solids membrane and fully kill the pathogens inside, therefore, a longer holding time after injection is desirable. The increase in dose required for solids can be seen to influence the “initial demand” on the product, after which achieved the PAA uptake drops and begins to degrade naturally (Figure 6).

Solids removal elevates some of the “initial” demand on PAA, allowing for a faster kill.

**PAA Viable Alternative Disinfectant**

Pilot studies, virus testing and water treatment studies are being conducted throughout the United States and the use of peracetic acid is becoming increasingly common in municipalities. Peracetic acid is a viable alternative disinfectant that produces no harmful by-products, achieves pathogen reduction, and is cost effective. Further work must be conducted with regulatory agencies involved in permitting in order to ensure full understanding of the product and to accurately monitor it.

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**Bibliography**


