# Mechanisms of Peracetic Acid Inactivation of Microbes

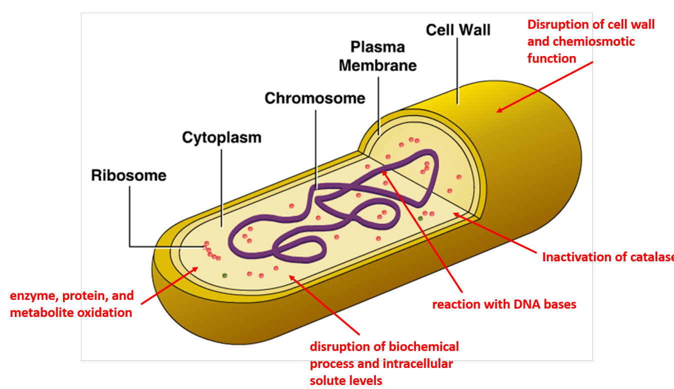
Peracetic acid (PAA) is a highly effective biocide that has gained in popularity over the past several years as a chlorine alternative for wastewater disinfection[1-3]. Increased interest in PAA is driven by several desirable characteristics, including:

- Efficacy at low concentrations
- Performance at low temperature
- Relative insensitivity to organic loading, total suspended solids and the presence of ammonia, nitrite and phosphates
- Ease of application
- No generation of chlorinated disinfection byproducts (DPBs), such as trihalomethanes (THMs) and haloacetic acids (HAAs), rapid degradation in the environment and low residual aquatic toxicity
- Favorable economics compared to several alternative disinfection technologies

While the benefits of PAA as a  disinfectant have become apparent, only limited work identifying the mechanisms by which PAA inactivates bacteria and viruses has been performed to date.

**PAA as a Strong Oxidizing Agent**

PAA is a strong oxidizer and, as a result, can attack a microbe in a variety of ways:




- Block[4] speculated that PAA functions much as other peroxides and oxidizing agents, in that sensitive sulfhydryl and sulfur bonds in proteins, enzymes and other metabolites are oxidized due to the release of active oxygen species by PAA.
- PAA reacts with double bonds, impeding molecular function.
- PAA acts as a protein denaturant.
- It has been hypothesized[4] that PAA disrupts the chemiosmotic function of the lipoprotein cytoplasmic membrane and transport processes through rupture or dislocation of the cell walls.
- Intracellularly, PAA may oxidize essential enzymes, disrupt biochemical processes and impair intracellular solute levels[5].
- It has also been demonstrated[6] that PAA acts on the bases of the DNA molecule, impairing replication.
- PAA will inactivate catalase, an enzyme within bacterial cells that inhibit reactive hydroxyl radicals[4].

**Synergistic Behavior with Hydrogen Peroxide?**

Peracetic acid solutions also contain hydrogen peroxide. DaVita Chemicals PureVita PAA solution contains 5.6% PAA by weight, but also 26.5% hydrogen peroxide. It is believed that the predominant disinfection comes from the peracetic acid, as PAA is a much more potent antimicrobial agent than hydrogen peroxide, especially at low concentrations. Several research studies have shown that there are virtually no synergistic effects between the PAA and hydrogen peroxide[8]. However, several investigations suggest that there may be enhanced microbial efficiency due to a potential efficacious synergy in PAA and hydrogen peroxide[7,8,9]. These investigations compared solutions containing "pure" PAA, hydrogen peroxide only and commercially available combinations of both PAA and hydrogen peroxide. The results suggest that the kinetic model of combined PAA and hydrogen microbial inactivation occurs in a staged process, including sensitization, catalase attack and irreversible attack leading to lysis. These works indicate that PAA must first initiate the attack on the cell, damaging the protective systems before the hydrogen peroxide can participate in actively in the bacterial inactivation reaction, and that once the catalase within the microorganism is inhibited by PAA, the hydroxyl radical can rapidly damage the cell.

**Conclusions**

A complete understanding of the PAA microbial inactivation processes is not yet at hand. However, there are many postulated pathways for PAA to damage and inactivate microbes, and it is clear that these multiple avenues of attack make PAA a very effective antimicrobial under a variety of conditions. Today, there is ongoing work using a variety of DNA and RNA analyses techniques that will continue to elucidate the nature and mechanism of PAA inactivation of bacteria and viruses.

**REFERENCES**


1. Baldry, M.G.C., French, M.S. and Slater, D. "The Activity of Peracetic Acid on Sewage Indicator Bacteria and Viruses". **Wat. Sci. Tech.** 24, 1991, p. 353.
2. Koivunen, J. and Henonen-Tanski, H. "Peracetic Acid (PAA) disinfection of primary, secondary and tertiary treated municipal wastewwaters". **Water Research** 39, 2005, p. 4445.
3. Rossi, S., Antonelli, M., Mezzanotte, V. and Nurizzo, C. "Peracetic Acid Disinfection: A Feasible Alternative to Wastewater Chlorination". **Wat. Env. Res.** 79, 2007, p. 341.
4. Block, S.S. Disinfection, Sterilization and Preservation. 4th ed., 1991, Lea & Febiger, Philadelphia.
5. Kitis, M. "Disinfection of wastewater with peracetic acid: a review". **Environ International** 30, 2004, p 47 – 54.
6. Tutumi, M., Imamura, K., Hatano, S. and Watanabe, T. "Antimicrobial action of peracetic acid". **J. Food Hyg Soc.** 15, 1973, p 116 – 230.
7. Alasri, A., Roques, C., Michel, G., Cabassud, C. and Aptel, P. "Bactericidal properties of peracetic acid and hydrogen peroxide, alone and in combination, and chlorine, formaldehyde against bacterial water strains". **Canadian J Micro** 38, 1992, p 635 – 642.
8. Flores, M., Lescano, M.R., Brandi, R.J., Cassano, A.E. and Labas, M.D. "A novel approach to explain the inactivation mechanism of *Escherichia coli* employing a commercially available peracetic acid". **Wat Sci and Tech.** 69, 2014, p 358 – 362.
9. Flores, M.J., Brandi, R.J., Cassano, A.E. and Labas, M.D. "Kinetic model of water disinfection using peracetic acid including synergistic effects". **Wat Sci and Tech.** 73, 2016, p 275 – 282.