

# Medical Applications of Plasma Activated Water and Its Combination With Silver Nanoparticles

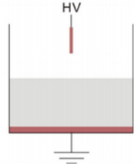
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## Abstract

This project deals with plasma-liquid interactions, specifically focusing on plasma activated water and its various uses in medicine, including antiviral applications as well as its utilization as a disinfecting agent. In addition, the antiviral and antibacterial effects of silver nanoparticles are examined. After exploring the antiviral aspects of both plasma activated water and silver nanoparticles, looking at various studies conducted, the combination of the two and its possible medical applications are discussed.

## Generation of Plasma Activated Water

- Cold plasma discharge in the air generates several species, including reactive oxygen species (ROS) and reactive nitrogen species (RNS)
- When plasma is created above water, some of these species are transported into the water below the plasma
- The transfer of these species results in plasma-activated water



Plasma reactor (gas phase discharge over liquid)  
HV: high voltage, red: electrodes, grey: liquid, cross-hatching: dielectric barriers (s)

## Plasma Activated Water as a Disinfectant

- In various studies, plasma activated water has been shown to be an effective agent for disinfecting surfaces and is also utilized for disinfecting medical devices/equipment



Duodenoscope (s)

- One study conducted showed that various strains of bacteria on a duodenoscope were affected by plasma treated water (treated with GlidArc reactor)
- Duodenoscope: lighted tube that allows doctors to examine patient's small intestine (duodenum) during certain procedures
- To analyze the disinfectant potential of plasma activated water, four different types of bacteria were used. Duodenoscope was contaminated in intestinal fluid that contains bacteria and then exposed to plasma activated water at different time intervals (5, 10, 15, 20, and 30 minutes) for 45 consecutive days
- Results indicate that, after 30 minutes of plasma activated water treatment, considerable reductions in populations of different bacteria strains were achieved
- This study demonstrates the decontamination potential of plasma treated water (s)

PAW antimicrobial activity

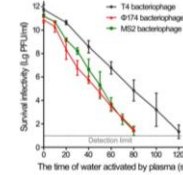
Strain name	5 minutes	10 minutes	15 minutes	20 minutes	30 minutes
<i>Escherichia coli</i>	+	+	+	+	+
<i>Staphylococcus aureus</i>	+	+	+	+	+
<i>Pseudomonas aeruginosa</i>	+	+	+	+	+

Note: + indicates the presence of bacteria in the culture media (uncontaminated generally); - indicates no bacteria (indicated by complete absence of growth in collections, that is, high level disinfection)

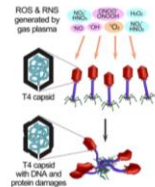
Abbreviations: PAW: plasma activated water  
Antimicrobial activity of plasma activated water. After 30 minutes of interaction with the plasma activated water, total inactivation occurred in all of the tested bacteria samples. total absence of microbial growth on culture samples = high-level disinfection (s)

## Antiviral Properties of Plasma Activated Water

- Plasma activated water treatment has also been shown to combat certain viruses in multiple studies via inactivation
- In one specific study, various suspensions of bacteriophages were incubated with plasma activated water to examine the effects of the plasma treated water on the pathogenic bacteriophages
- Within two minutes of treatment, the survival infectivity of the bacteriophages decreased to almost undetectable amounts
- Based on the results, the plasma activated water effectively inactivated bacteriophages tested



Data shows the inactivation of bacteriophages over 2 minute time period (s)



- The inactivation of the bacteriophages happens because the ROS and RNS in the plasma activated water cause damage to both nucleic acids and proteins that make up the capsids of the viruses
- This study demonstrates the effective utilization of plasma activated water to potentially combat various types of particular viruses (s)

## Silver Nanoparticles Utilized as Antiviral Agent

- Although silver nanoparticles have mostly been examined for their potential against bacteria and have been studied for these effects, they have also shown to be combative against multiple viruses (HIV, hepatitis B virus, herpes simplex virus, and several others)
- Silver nanoparticles are active against viruses because the nanoparticles block the attachment of the virus to healthy cells, causing the virus to be unable to enter the cell and therefore, preventing the cell-to-cell spread of the virus
- Utilization of silver nanoparticles as an antiviral treatment presents possible opportunities for more effective treatment, as there is a lower possibility of viruses to develop resistance to the nanoparticles' inhibiting effects (s)

## Plasma Activated Water With Silver Nanoparticles

- Plasma activated water on its own has been shown to work against several types of viruses and bacteria, but when combined with silver nanoparticles, there may be a greater potential of effectiveness against these viruses and bacteria
- The generation of plasma activated water with silver nanoparticles is something that has not been explored very in-depth, but as more research and experimentation is conducted, this combination may present a more effective antiviral agent than the two as separate treatments

## Implications for the Future

- While plasma activated water has demonstrated effectiveness as a disinfectant, the substance needs to be studied more in order to be fully understood and utilized as a disinfecting agent, potentially replacing current disinfecting methods
- Although various studies have proven the antiviral effects of plasma activated water, the mechanism of inactivation of viruses is not fully understood yet – more experimentation and research needs to be conducted
- With time and more research regarding the combination of plasma activated water and silver nanoparticles, the use of the two together could possibly provide a more effective and efficient method of antiviral/decontamination treatments

## References

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