

## Bactericidal Mechanisms-of-Action of Copper and Silver Ions

The inhibitory effect that metals, and particularly the group classified as “heavy metals,” have on the bacteria that can cause infections has been known as far back as 4000 B.C. Copper and silver ions, as well as most heavy metals, such as zinc, nickel, lead, and tin, are known to react with protein molecules containing amino, hydroxyl, imidazole, carboxylate, thiol, and/or phosphate particles.

The accumulation of copper ions in the cell wall protein results in the failure of key enzymes involved in the selective transmittance of specific nutrients into the bacterial cell wall and membrane. At a threshold value of approximately 0.3 mg/L copper, the transport of foreign or undesirable chemicals, including silver ions, into the cytoplasm of a bacterial cell can occur.

The effect of the copper complexing with the chemical groups of proteins in the cell wall is to cause steric hindrance where respiratory enzymes can no longer react with the respective substrate; in other words, the reactive site of the enzyme protein is blocked from substrate attachment. The resultant failure of the respiratory enzymes causes cellular death.

Silver ions cause enzyme proteins to denature to the point that structural changes to the enzyme results in the failure of any further functioning. It has been shown in that silver ions, once they have penetrated the cell walls and membrane of both Gram-positive and Gram-negative bacteria, reach the genomic DNA, which results in the failure of the bacterial cells to reproduce.

***The synergistic response of copper combined with silver explains the secondary effect where copper affects the proteins of the cell wall, which allows silver to enter the cytoplasm and react with the genomic DNA.***

In summary, there are several mechanisms at work involving the effect of copper and silver ions on bacterial survival and growth. The complexing of these two metal ions with chemical groups common to the structural proteins of cell walls, enzyme proteins, membranes, DNA, and RNA causes cell death at threshold concentrations and cellular dormancy at sublethal concentrations.

The efficacy of copper and silver ions in various ratios has been demonstrated to penetrate biofilms and to destroy the microbial communities comprising the biofilm. It has been shown that resistance to these metal ions, when maintained at threshold bactericidal levels in the ionic form, has never been reported.

The control of *Legionella* spp. with copper-silver has additional potential benefits when compared to other oxidizing types of bacterial agents. Both copper and silver ions, when complexing with proteins, decrease in concentration as the ions are taken out of solution.

In the case of a cooling tower, the copper and silver ions will react with biofilm accumulation with the result that the aqueous discharge will actually contain decreased toxic metal concentrations, which otherwise could affect a biologic waste treatment plant.

### References

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