Silver nanoparticles are known for their antimicrobial activities, but they have not been applied to many industries yet. Studies show that there are ways to synthesize silver nanoparticles in not only a cost-effective way but also an environmentally-friendly way using non-toxic reagents making them safer to be applied to industries. Silver nanoparticles have the potential to be used in the cosmetics industry, the food industry, and the medical industry. People are interested in this because in each of these industries there is the potential to create safe antimicrobial silver nanoparticles to be applied in many ways.

In the article “Silver nanoparticles as a safe preservative for use in cosmetics,” silver nanoparticles are applied to the cosmetics industry. Cosmetics require preservatives to prevent contamination as they are being produced and as consumers use them. The current preservatives, such as phenoxyethanol and parabens, safety is questionable due to the fact that they stimulate the skin and increase sensitivity to ultraviolet light. In this study, silver nanoparticles were tested to examine the effects on microorganisms, the permeability on human skin, and the cytoxicity in human skin cells under ultraviolet B irradiation. To carry out this study, an array of methods was used. The size of the silver nanoparticles were analyzed using laser scattering. The results show that the silver nanoparticle solution did not change color (light yellow) or show any signs of sedimentation after being stored for a year. Laser scattering revealed that the particles had an average diameter of 730.5nm. The antimicrobial activity was measured using a mixed bacterial suspension and an organism count was performed at 7, 14, and 21 days after silver nanoparticles
were introduced to the suspension. Results showed that at 1 ppm, silver nanoparticles exhibited preservation against the bacterial suspension. The ability to penetrate human skin was tested using inductively coupled plasma mass spectrometry (ICP-MS) and ICP-atomic emission spectrometry (ICP-AES). Silver was not detected at all under the skin after exposure for 24 hours. A UV radiometer was used to determine the sensitivity of silver nanoparticles and a common cosmetic preservative, methylparaben (MP), to UVB light. After being exposed to UV irradiation, any cell death was determined using fluorescent microscopy. This study proved that silver nanoparticles did not induce cell death of keratinocytes; however, the methylparaben did induce cell death. The results of this study show that silver nanoparticles have the potential to be used in the future as a safe preservative in the cosmetics industry due to their antimicrobial activity and their inability to penetrate human skin.

In the article “Antibiotic glass slide coated with silver nanoparticles and its antimicrobial capabilities,” applications in the food industry are analyzed. In a food processing area, microorganisms can form biofilms, which are a community of bacterial cells, by attaching to solid surfaces (such as glass); biofilms are more resistant to antimicrobial treatments than individual bacterial cells making them difficult to remove. The purpose of this study is to use silver nanoparticles absorbed on a glass surface to prevent contamination and the creation of biofilms during the food manufacturing process. In order to create a film of silver nanoparticles on the glass it is important that it is not easily able to be washed off, which is why a method using a coupling agent, 3-aminopropyltriethoxysilane (APTES), is suggested in this article. The coupling agent allows the silver nanoparticles to attach to the glass tightly yet still be able to release enough silver ions to prevent biofilms from forming. In order to perform this study, silver nanoparticles were synthesized using non-toxic reagents. The glass was prepared and then
immersed in the silver solution for one day. It was then rinsed with ethanol and dried. Transmission electron microscopy (TEM) was used to show that the silver was the suitable size and evenly dispersed. A UV-Vis spectrophotometer was used to prove silver nanoparticles were present on the glass. The data from this showed that the silver nanoparticles didn’t experience any change when introduced to the glass slide. To test the efficiency of the silver nanoparticle coated glass slide, a mixture of *E. coli* was spread over the coated glass and uncoated glass. The results show that there is no bacterial growth on the coated glass, but there was growth on the uncoated glass confirming that silver nanoparticles coated on glass can serve as an efficient antimicrobial agent. This method is cost-effective and uses common, cheap, and non-toxic chemicals which makes this applicable in the food industry. This method is currently being extended to other metal nanoparticle coatings of different substrates, not just limited to glass. In the article “Chemical assembly of silver nanoparticles on stainless steel for antimicrobial applications,” silver nanoparticles are assembled onto stainless steel using the same coupling agent, APTES, as in the previous article. These two studies find similar results in that the silver nanoparticles on both substrates are highly effective in inhibiting the growth of bacteria, reaffirming that silver nanoparticles have great potential to be used as an antimicrobial agent in the food industry.

The antimicrobial properties of silver nanoparticles can be used in a wide range in the medical field. In the article “Antimicrobial properties of hydrated cellulose membranes with silver nanoparticles,” silver nanoparticles are used in conjunction with cellulose membranes to create an effective antimicrobial wound dressing material for wounds and burns. Microbial cellulose membranes are effective at helping to heal wounds and burns because they have a high water holding capacity so they do not dry out. This factor can also create high humidity around
the wounded area which can allow bacteria to grow, and cellulose is not known to possess any antimicrobial properties. In this study, silver nanoparticles are incorporated into cellulose membranes by chemical reduction to create a wound dressing that will prevent the growth of bacteria, yet still allow the wound to heal properly. X-ray diffraction (XRD) was used to verify that silver nanoparticles were fabricated on the cellulose membrane. XPS spectroscopy was used to determine interaction between the silver nanoparticles and the cellulose membrane. In order to evaluate the antimicrobial activity of the membrane with nanoparticles, *E. coli* and *S. aureus* were tested as a control and on the membrane. On the cellulose membrane with silver nanoparticles, the amount of bacteria was reduced by 5 to 6 orders of magnitude and the antimicrobial efficiency was greater than 99%. On the cellulose membrane without silver nanoparticles, the amount of bacteria increased after 24 hours, suggesting that the humidity provided an environment for the bacteria to grow. This study shows that silver nanoparticles can be used with cellulose membranes to create a dressing for wounds that has highly efficient antimicrobial properties. A similar study was performed in “Antibacterial applications of silver nanoparticles synthesized by aqueous extract of azadirachta indica (Neem) leaves.” To synthesize the silver nanoparticles used in this study, an environmentally friendly aqueous reducing agent was used made from Neem leaves. The effect of these synthesized nanoparticles was tested in a cotton cloth against *E. coli*. The results show that this way of synthesizing silver nanoparticles and then using it in conjunction with a cotton cloth can help cause sterilization when dealing with bacteria and wounds.

In “A novel approach for studying the combined antimicrobial effects of silver nanoparticles and antibiotics through agar over layer method and disk diffusion method,” the combined effects of silver nanoparticles and antibiotics is studied. Antibiotics are becoming
increasingly less sensitive to many people and organisms which is why researchers starting investigating silver nanoparticles as an antimicrobial agent in the field of medicine. XRD analysis was used to characterize the silver nanoparticles and confirm size. Thin layer chromatography was used to separate compounds in the antibiotics. When silver nanoparticles and antibiotics worked together, an increase was observed in the zone of inhibition (a minimum increase of 2-4 mm and a maximum of 24-28 mm in the diameter). Based on this study, it can be concluded that silver nanoparticles and antibiotics increase inhibitory effects when given together. Potentially, silver nanoparticles could be used as an antimicrobial agent equivalent to current antibiotics on the market that are used against bacterial infections. The article “Silver nanoparticles as a new generation of antimicrobials,” also discussed the use of silver nanoparticles as an antimicrobial agent that can be used against drug-resistant pathogens. It noted that silver nanoparticles could have a diverse range of use in the medical field such as wound dressings and silver coated medicinal devices. Another article titled “Cationic antimicrobial peptides and biogenic silver nanoparticles kill mycobacteria without eliciting DNA damage and cytoxicity in mouse macrophages,” further explores the possibility of using silver nanoparticles as an antimycobacterial agent. Mycobacterium pathogens include mycobacterium tuberculosis (tuberculosis) and mycobacterium leprae (leprosy). The basis of this study was because there are drug-resistant strains of mycobacteria that are becoming more difficult to provide treatment for. The results of this study showed that the combination of silver nanoparticles and antimicrobial peptides exhibited effects that can be used as an antimycobacterial template against mycobacterium.

The antimicrobial ability of silver nanoparticles can be applied to many different industries, including cosmetics, food, wound dressing, and the medicinal fields. When used in
these industries it is important to synthesize silver nanoparticles in the safest non-toxic way to ensure the safety of those using products or coming into contact with these products. In “Silver nanoparticles with gelatin nanoshells: photochemical facile green synthesis and their antimicrobial activity,” silver nanoparticles are prepared using green synthesis. This involves using UV light from the sun as a non-toxic reducing agent and gelatin as a capping agent which caused the silver nanoparticles to stabilize and assemble into their proper shape. This way of synthesizing silver nanoparticles is cheap and the gelatin is biodegradable and non-toxic. A UV-Vis spectrophotometer was used to record absorption spectra in the samples of prepared silver nanoparticles. The particle size was determined using dynamic light scattering. Atomic force microscopy provided high-resolution surface imaging to determine particle size and distribution. Antimicrobial activity of the green synthesized silver nanoparticles was tested against three classes of microorganisms. The antimicrobial activity was confirmed and the number of microorganisms decreased. This study of green synthesis provides an inexpensive way to synthesize silver nanoparticles while maintaining their antimicrobial effect on microorganisms which can be very useful. Another type of green synthesis was performed in “Green synthesis of silver nanoparticles using citrus reticulata juice and evaluation of their antibacterial activity and cytotoxicity against melanoma-B16/F10 cells.” This study synthesized silver nanoparticles using citrus reticulata juice as the reducing agent at room temperature. The silver nanoparticles were then characterized using an array of techniques, and their antimicrobial activity was tested with tetracycline and penicillin against bacteria. This combination showed a high inhibition rate on the bacteria. Then the cytotoxic effects were tested on melanoma and evaluated which showed a maximum inhibition of 31.29%. This type of synthesis is another example of how to prepare
silver nanoparticles in a safe environment to then be used in other fields of study as an antimicrobial agent.

Silver nanoparticles exhibit antimicrobial effects as proven in all of these studies. There are also an assortment of ways to synthesize the silver nanoparticles using safe non-toxic reagents that are also environmentally friendly. The next step is to apply the silver nanoparticles in ways that could be used in everyday life, whether as a preservative in cosmetics, a way to prevent bacterial growth in the food industry, or used with an antibiotic to help treat bacterial infections or wounds.

Bibliography


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