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Math, Physics & Chemistry

Mussel's powder engineered to kill pathogens

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ABSTRACT

Adhesive used by mussels to stick to surfaces like ship hull, rocks, and piers, was reengineered to create powder that can kill pathogens. When hydrated, the powder generates a commonly disinfectant, hydrogen peroxide, and effectively disinfected two types of bacteria and two types of viruses

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Hydrogen peroxide is a commonly used disinfectant. A typical household may have a bottle of 3% hydrogen peroxide solution for disinfecting minor cuts and scrapes. Concentrated hydrogen peroxide is also used in municipal wastewater and drinking water treatments, in petrochemical refinery applications, and in bleaching of paper products. However, concentrated hydrogen peroxide is explosive and very dangerous to store and transport. A dilute solution of hydrogen peroxide is safe but very bulky and not very portable. Our research group developed a powder that can generate hydrogen peroxide when the powder is hydrated in water. This technology utilizes a unique chemistry found in mussel adhesive proteins.

Marine mussels secrete adhesive proteins that enable these organisms to bind to various surfaces under water (ship hulls, rocks, piers, etc.). One of the key ingredients in these adhesive proteins is a compound called catechol. Many research labs around the world have utilized catechol to create tissue adhesives and wound dressings so that they can stick better to wet tissue surfaces. One interesting phenomenon about catechol is that under certain conditions, it generates hydrogen peroxide as a byproduct. In this study, we wanted to use this particular ability of catechol to create a powder that can release hydrogen peroxide for disinfecting various pathogens, such as bacteria and virus.

Our research group created micron-sized powder-like particles that contain catechol. These particles are solidified in an emulsion (like tiny bubbles in soapy water) and adopted the spherical shape and size of these tiny bubbles. To generate hydrogen peroxide, the particles are hydrated in a neutral or slightly basic solution (blood, seawater or solutions containing backing soda are slightly basic). The oxygen in the solution oxidizes the catechol to generate hydrogen peroxide as the byproduct. Because these particles are so small, they have a large surface area and can release the hydrogen peroxide very quickly. These particles can continue to generate hydrogen peroxide for over four days. These particles can be deactivated when placed in an acidic solution (similarly to an orange juice) and reactivated in a slightly basic solution.

These particles were used to disinfect two types of bacteria and two types of viruses. The bacteria strains were *Staphylococcus epidermidis* (*S. epidermidis*) and *Escherichia coli* (*E. coli*). *S. epidermidis* is commonly found on the skin and is responsible for hospital-acquired infection. On the other hand, *E. coli* is commonly associated with food poisoning. These bacteria strains were completely killed within six to twenty four hours. Our particles also reduced the infectivity of an enveloped virus (bovine viral diarrhea virus) and a non-enveloped virus (porcine parvovirus) by more than 99.9% within 12 hours. These are standard viruses used by the United States Food and Drug Administration (FDA) to test virus removal operations while developing new vaccines.

In conclusion, catechol was incorporated into micron-sized particles. These powder-like particles generated hydrogen peroxide when they were hydrated in a slightly basic aqueous solution. The powder does not contain hydrogen peroxide and converts oxygen found within the aqueous solution into hydrogen peroxide. The released hydrogen peroxide effectively disinfected two types of bacteria and two types of viruses.

This technology takes advantage of a unique chemistry found in mussel adhesive proteins to create a novel powder-based disinfectant. This powder is lightweight and portable when compared to a large volume of diluted hydrogen peroxide solution found typically in a household. This powder has many potential applications. It could potentially be used as a portable disinfectant for disinfecting open wounds to prevent bacterial and viral infection (i.e., rabies virus, tick-borne virus, etc.). It could also be used for disinfecting hospitals or surgery suites in underdeveloped countries.