THE SUPER-CLEAN TEAM

The battle to beat disease-causing microorganisms has found a new champion in a highly effective series of smart and effective disinfectants made possible by HKUST technologies. The multifaceted innovations by chemical and biological engineering expert Prof King Lun Yeung and health and environmental safety specialist Prof Joseph Kwan combine their expertise to develop novel materials and technologies to beat back airborne diseases such as Middle East Respiratory Syndrome Coronavirus (MERS-CoV), influenza H1N1 and H3N2, and emerging hospital superbugs, including the methicillin-resistant *staphylococcus aureus* (MRSA), carbapenem-resistant enterobacteriaceae (CRE) and the notorious vancomycin-resistant enterococci (VRE). The pair also developed technologies to fight waterborne microorganisms, for example, *E. coli* and *legionella pneumophila* bacteria, as well as microorganisms that cause bad odor in drainage and sewer.

At the heart of the scientists' work lie three guiding principles:

• A "Safer-by-Design" approach that focuses on safety from inception of the idea – HKUST disinfectant products are designed with minimized use of ingredients or components. For example, while a typical shampoo product contains 20-30 ingredients, each HKUST disinfectant technology uses just two to three ingredients.

• Maximum effectiveness using the least amount of chemicals at the lowest cost – this has led to the adoption of the "continuous release" concept found in sustained drug delivery. The HKUST disinfectants are delivered in a very low dosage over a period of time to enable "release-killing", which then maintains the effectiveness of microbial sterilization over weeks or years. The dosage methodology also helps to reduce impact on the environment.

• Engineering that enables the technologies to be responsive to environmental cues – resulting in coated surfaces that can detect human touch and contaminating substances and deliver the disinfectant accordingly.

> "My goal is not a scientific journal paper, limited to what works in the lab, but a product that can eventually be brought to market"

PROF KING LUN YEUNG
Professor of Chemical and Biological Engineering, Environment and Sustainability

Prof Yeung's research, initiated in 2002 with a grant from Hong Kong's Innovation and Technology Fund, was spurred on by the SARS outbreak in 2003, the "Mexican" human swine flu outbreak in 2009, and management of health and safety concerns for major public events, such as the Beijing Olympic Games in 2008. While his goal is commercialization, the aim is not to operate his own business but to license the resulting technologies to up-and-running companies for speedier development to market and keep his own focus on innovation.

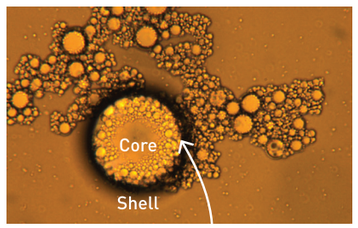
All the HKUST innovations adhere to US Food and Drug Administration and US Environmental Protection Agency standards for the use of germicides and their dosages.

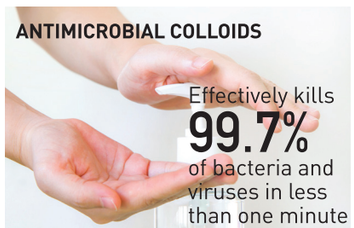
Surface Disinfection

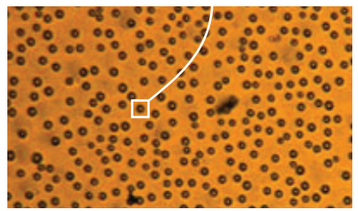
Smart Antimicrobial Coating

Chlorine dioxide, a disinfectant widely used in the food industry, was stored in smart capsules that control the release of the disinfectant, so that an extremely low amount is still potent enough to eliminate microbes. Catalytic-dyad and anti-adhesion materials engineered into the capsule provide contact-killing and prevent bacteria from contaminating the coating. They also enable the coating to sense touch from hand and contamination by droplets to automatically release larger amounts of the disinfectant to clean and disinfect the area of disease-causing microbes, viruses, spores, and mold. After numerous refinements of the release strength of the ingredients and encapsulation design, the biodegradable coating was shown to effectively kill 99.99% of bacteria, viruses, and spores within one minute of contact and remain effective for 30 days. The surface coating technology has been licensed to Greenland Biotech Ltd.

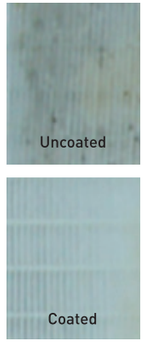
Surface Disinfection
HKUST's antimicrobial disinfection technology can be used in high-traffic surfaces. Smart capsules with diverse combinations of materials can achieve different effects, such as antifouling and slow release for continuous disinfection.



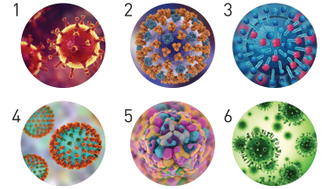




AIR DISINFECTION



HKUST's novel air purification technology was made available on the market as a household purifier in 2017



HKUST's smart coating can kill:
1. MERS-CoV: 98.8%
2. Influenza A virus: > 99.999%
3. Influenza B virus: > 99%
4. H3N2 Hong Kong flu virus: 99%
5. Enterovirus 71: > 99%
6. H1N1 swine flu virus: > 99.9%

Air Disinfection

Conventional HEPA (air) filters can sift and capture airborne microorganisms but the microbes may still remain viable, carrying the risk of recontamination. Applying HKUST's long-lasting antimicrobial coating technology to such filters has been shown to eliminate 99.99% of airborne bacteria and viruses, including MERS-CoV and influenza strains. The novel coating inactivates airborne microorganisms as they pass through the filter, preventing the accumulation of microbes on the filter's surface. Industry partner Chiaphua Industries Ltd has licensed and commercialized the technology into a product line called Germagic™.

Antimicrobial Colloids

A related smart coating technology built from multi-level antimicrobial polymers kills microbes and prevents them from fouling surfaces. Findings show it eliminates 99.7% of bacteria and viruses in less than a minute. The technology can be formulated into different products including surface coatings, fabric softeners, paints, filters, hand soap, and disinfectant to afford long-term disinfection and protection against diseases. Clinical trials at the Kowloon Hospital show that it can drastically decrease bacteria on patient privacy curtains for more than three weeks. A study at elderly homes shows that its use on bed linens and pillows reduces microbial contaminations by more than 90% over seven days.

Water Disinfection

Tap Water

Current disinfection technology uses high-input voltage pulsed electric field technology, requiring up to 100,000 volts and creating potential electrical hazards for operators. HKUST's Pulse Water renders microorganisms in water inactive by subjecting them to a repeated low-voltage pulsed electric field. This causes cell membrane pores to dilate, allowing chlorine in the water to rapidly kill the microorganisms. The portable, battery-operated technology has been miniaturized to maximize usage, being suitable for faucets and showerheads as well as public water systems. The HKUST researchers are also working with the Hong Kong government's Water Supplies Department on a two-year project to develop and field-test an antimicrobial formulation to keep pumps and pipelines clean.

Malodor Control

Strategies for dealing with unpleasant smells in a mixed-use, crowded urban environment have, to date, proved ineffective, expensive, or both. Now, a HKUST malodor control hydrogel, combining biocides, metabolic inhibitors, and catalytic agents, is being brought to market to suppress malodorous compounds. The technology reduces foul-smelling hydrogen sulfide to below 0.1 part per million (ppm) in sewers, drainage systems, as well as wet and dewatered sludge. Originally funded by Hong Kong's Innovation and Technology Fund, work is ongoing with the Hong Kong government's Drainage Services Department and Environmental Protection Department.

The hydrogel technology is now deployed in 200 locations across Hong Kong to control malodor. Only 4kg of hydrogel is needed to clean 200,000m^3 of sewage water for 30 days.