Enhancing Button Battery Ingestion Safety Using a Multifunctional Hydrogel Composite

Belal, Jomanah (School: Al-Hussan Modern National School for Girls - Al-Jubail)

Button Battery Ingestion (BBI) constitutes a global emergency, reporting over 300,000 cases annually, primarily affecting children under six due to natural exploration, resulting in hundreds of fatalities. When a battery lodges in the esophagus, severe tissue burns begin as saliva completes an external circuit that drives water electrolysis, generating corrosive hydroxide ions, leaving a critical gap for battery-integrated BBI mitigation. To address this hazard, a novel tri-functional defense mechanism was developed using a sodium alginate hydrogel reinforced with poly(vinyl alcohol), integrated with Tinospora cordifolia bitterant and a visual dye. Upon saliva exposure, the composite rapidly swells to disrupt current flow, rendering the battery electrochemically inactive to protect against tissue necrosis while enabling deterrence and traceability. The matrix was synthesized at optimized ratios and crosslinked with $Ca^{2?}$ (0.05–0.4 M) to tune structural integrity and porosity. The optimized formulation Alg:PVA 1:4, 0.2 M $Ca^{2?}$ achieved ~200% and 510% increases in swelling within 5 minutes under simulated saliva conditions without dissolution. This expansion reduced the electrochemically active area by 79.75% and lowered corrosive pH elevation by 53.77%. Saliva contact triggered an autonomous voltage drop that successfully inhibited current generation, while the composite preserved standard operating voltage in dry conditions. Controlled release tests confirmed diffusion of a natural bitterant and a visual tracer, validating its ability to deter mouthing and improve detectability. Ultimately, this research potentially advances consumer electronics safety with a cost-effective solution that prevents lethal injury and converts dormant threats into self-securing technologies.

Awards Won:
Second Award of $2,400