Slide 1: Electrochemical Thermodynamics

"Thank you. To understand how our reactor captures heavy metals passively, let's look at the theoretical framework. The core principle is the spontaneity of the reaction, described by the Gibbs Free Energy equation. We calculated theoretical values for our target contaminants—Copper, Lead, and Zinc—against our sacrificial Aluminum anode.

Because Aluminum has a low standard reduction potential, it creates a large positive cell potential when paired with these metals, ranging from +0.90 Volts for Zinc up to +2.00 Volts for Copper. Consequently, the highly negative Gibbs Free Energy values mathematically prove that cementation is thermodynamically spontaneous.

To overcome the 'Passivation Paradox'—where aluminum's oxide layer blocks reactions—we rely on the Capacitance Theory. The thin oxide layer acts as a dielectric, allowing electron transfer. This is exactly why we target mine wastewater: the acidity dissolves the oxide shell, unlocking the aluminum core so the reaction can proceed."

Slide 2: Primary Mechanism: Reductive Cementation

"This brings us to the core engine: Reductive Cementation. This is essentially a metal displacement process split into two simultaneous half-reactions.

In the Anodic Reaction, our Aluminum screens act as the electron donor. The aluminum oxidizes, releasing electrons and dissolving into the solution. Immediately, the target contaminants—the Copper, Lead, and Zinc ions—consume these electrons in the Cathodic Reaction. This reduces them from a soluble ionic state into solid, elemental metals that plate directly onto the screen."

Slide 3: Secondary Mechanism: Adsorption and Co-precipitation

"While cementation is the primary driver, Adsorption and Co-precipitation act as a critical secondary mechanism, especially for polishing the water and capturing stubborn metals like Zinc. This happens in three stages.

First, protons in the acidic water are reduced to Hydrogen gas, causing a localized pH rise right at the screen's surface. Second, this local pH shift causes dissolved aluminum ions to form fluffy Aluminum Hydroxide flocs. Finally, these flocs act like a chemical sponge during the Adsorption phase, physically trapping dissolved metal ions. This is crucial for Zinc, which precipitates better at higher pH levels, ensuring contaminants are captured even if direct cementation is slow."

Slide 4: Novelty of the Study

"Finally, we distinguish our proposed reactor from existing research in three critical ways.

Currently, Zero-Valent Aluminum is typically used as loose, hard-to-recover powders, or in electrocoagulation setups that require continuous external power. Most studies also evaluate them as standalone main treatment units.

In contrast, our Perforated Screen Reactor is a passive, flow-through system that requires zero electricity. We specifically engineered it as a pretreatment 'roughing filter' to capture bulk metals before they reach the main treatment plant. This modular design offers a practical foundation for future scale-up, completely solving the handling issues associated with aluminum powders."