Application of AI-Assisted In-Situ Neutralization Using Magnesium-Based Reagents for Copper Removal in Tailings Water

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ABSTRACT

Introduction: Tailings ponds at mine sites pose long-term risks due to the potential release of acid mine drainage and dissolved metals such as copper. Conventional treatment approaches typically involve pumping large volumes of water to centralized facilities and using aggressive reagents like lime, which can lead to operational complexity, sludge production, and secondary contamination. To address these challenges, this study explores an in-situ treatment strategy that combines slow-release magnesium-based reagents with autonomous, sensor-driven dosing systems.

Methodology: A spatially resolved treatment plan was developed by generating a digital twin of the tailings pond using bathymetric data and real-time water quality measurements, including pH, oxidation-reduction potential (ORP), electrical conductivity (EC), and total suspended solids (TSS). These data points were collected at multiple depths to build a three-dimensional model of the pond's chemical profile.

The neutralization reagent used was a magnesium oxide-based formulation with slow-release characteristics, chosen for its buffering capacity and ability to precipitate dissolved metals without exceeding safe pH thresholds or promoting scale formation.

To optimize dosing, an AI-based control algorithm was deployed onboard an unmanned dispensing vessel. The AI system used a supervised learning approach, initially calibrated using historical bench-scale data and prior injection events. During field deployment, the system continuously analyzed water quality readings from each location to:

- Predict the local metal load and buffering capacity,
- Calculate the minimum effective reagent dose needed to reach target pH and metal precipitation thresholds,
- Adjust the slurry concentration, injection rate, and sequencing for each pass.

The AI model included feedback mechanisms that allowed for learning from previous dosing iterations. After each injection cycle, post-treatment water quality was re-analyzed, and the model parameters were refined to improve dosage accuracy. This real-time adaptation enabled precise reagent delivery with minimal waste and avoided both underdosing and pH overshoot.

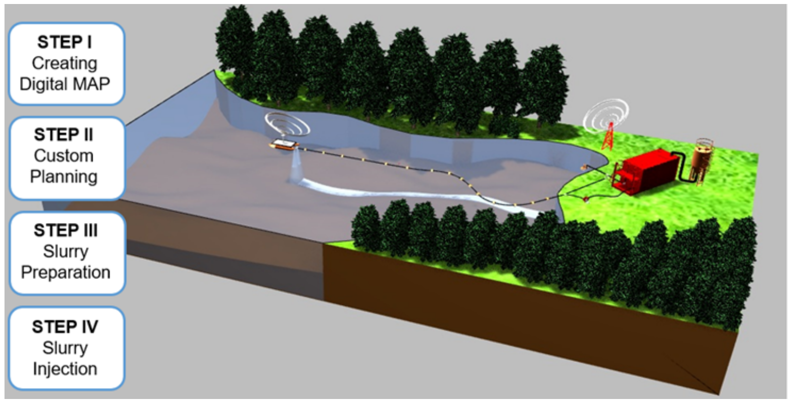

Figure 1: Schematic of in-situ water treatment system

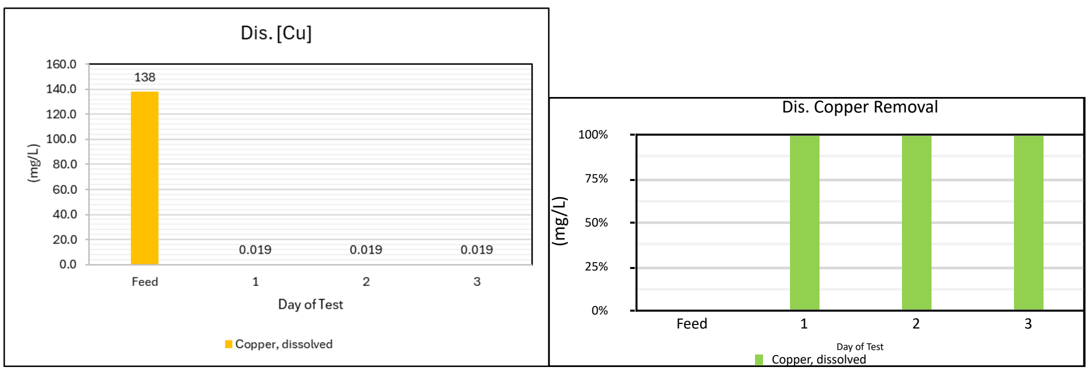

Figure 2: Copper concentration and removal efficiency by magnesium oxide-based reagent during the pilot study

Results and Conclusions: The in-situ system was tested in a pilot deployment targeting copper concentrations in excess of 130 mg/L. Following the initial injection, the AI system used inline sensor feedback to recalibrate reagent volumes across treatment zones. Within 24 hours, copper concentrations were reduced to below 0.02 mg/L, achieving a removal efficiency of 99%.

The pH stabilized between 8.6 and 9.0, within the optimal range for copper hydroxide precipitation and well below levels that could trigger secondary metal remobilization. This stability was attributed to both the buffering behavior of the reagent and the dynamic dosage adjustments made by the AI controller.

While copper was the primary target, the treatment also resulted in the reduction of other metals such as manganese and chromium to near or below analytical detection limits, though these results were secondary.

This study demonstrates that an AI-assisted, sensor-integrated reagent dosing platform can deliver effective, site-specific metal removal in complex tailings environments. By leveraging real-time data and adaptive process control, this approach offers a technically sound, scalable alternative to conventional water treatment systems—particularly in remote or infrastructure-limited settings.

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