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Hydrogeochemical Modeling of Control Strategies for Acid Mine Drainage and Water Resource Protection

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INTRODUCTION & AIM

Environmental hazards from mine waste dumps, particularly acid mine drainage (AMD) and the transport of toxic metals to surrounding water bodies and soil, pose significant challenges in metal mining operations. These pollutants threaten water resources and ecosystems, requiring effective management. This study presents an integrated, preventive approach to control AMD generation and protect nearby rivers, lakes, and springs. By focusing on the principle of "prevention prior to remediation," the research explores pollution control at the source by reducing contact between water, oxygen, and sulfide-bearing materials. The study uses numerical simulations of methods like dry cover systems, geosynthetics, and neutralizing agents for encapsulating acid-generating waste, with laboratory-scale validation. The aim is to provide practical solutions for improving mine waste management and protecting water resources and ecosystems.

METHOD

This study used numerical modeling to assess the effectiveness of pollution control methods in preventing (AMD) formation in mine waste dumps. The modeling included dry cover systems with compacted clay, geosynthetics, and recycled materials, along with the encapsulation of acid-generating wastes using neutralizing agents. Laboratory tests, such as column leaching and tailings disposal simulators, were conducted to evaluate metal contamination in the leachates. The combination of modeling and physical tests provided insights into the effectiveness of these methods in reducing AMD formation and metal contamination.

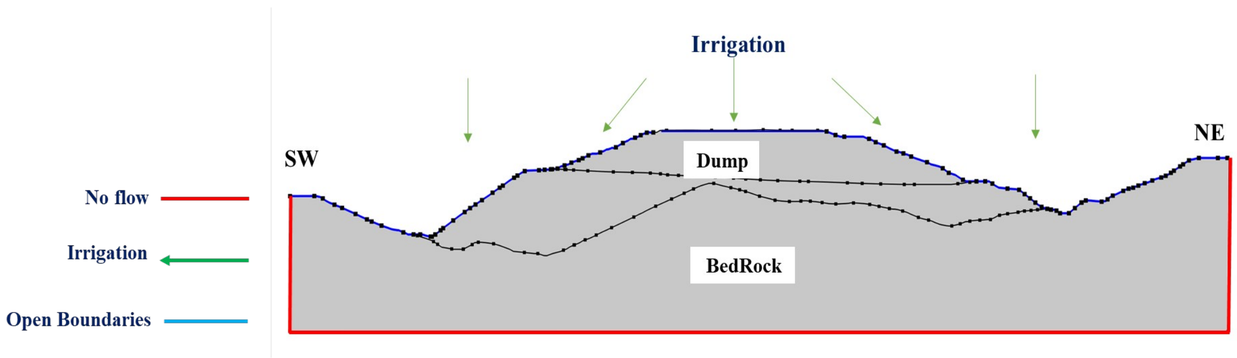

Fig1. Conceptual model with model boundary conditions

RESULTS & DISCUSSION

The results of this study demonstrate the effectiveness of the integrated pollution control methods in reducing the formation of (AMD) and minimizing metal contamination. The numerical simulations showed that the combination of a 0.15 m thick dry cover, neutral waste layering, and encapsulation with neutralizing agents could reduce oxygen penetration by up to 52%, significantly decreasing AMD generation. The laboratory-scale physical model confirmed these findings, as it revealed that the pH of the leachate increased from 2.3 to 6.4, indicating a reduction in acidity. Furthermore, the concentrations of toxic metals such as iron and lead were reduced by approximately 63% and 48%, respectively, showing the potential of these methods in mitigating metal leaching.

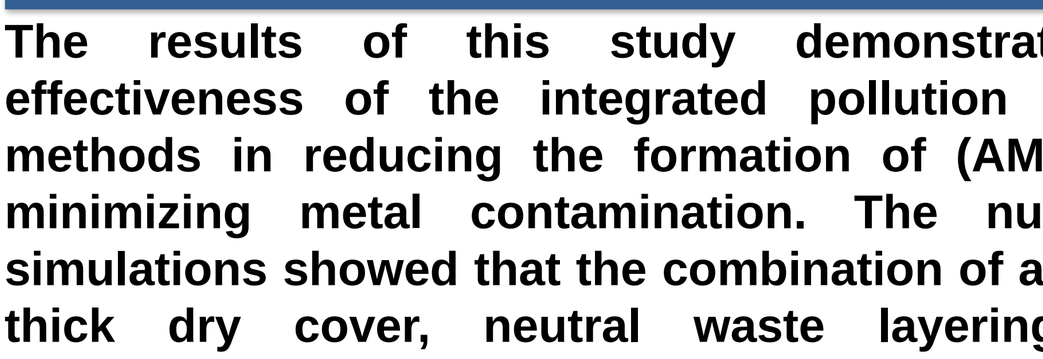

Fig 2. Modeling results before the use of dry cover and remedial measures on the mine waste dump

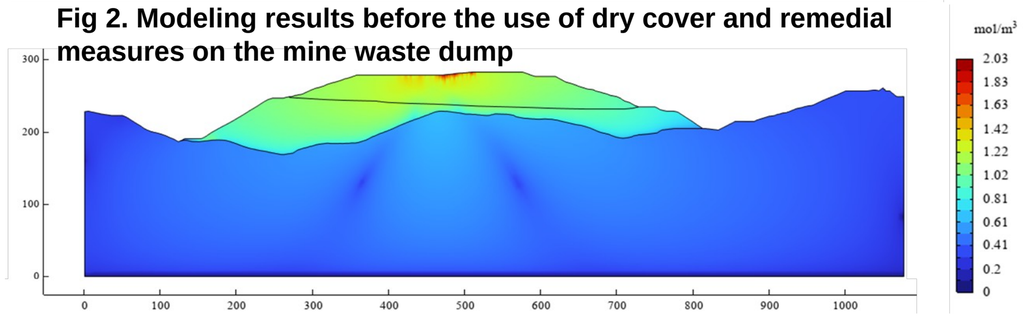

Fig 3. Modeling results after the use of dry cover and remedial measures on the mine waste dump

CONCLUSION

This study demonstrates that integrated pollution control methods, such as dry covers, neutral waste layering, and encapsulation, effectively reduce AMD and metal leaching in mine waste dumps, improving toxicity reduction and protecting nearby water bodies and ecosystems. These findings provide a practical framework for better environmental management in mining operations.

FUTURE WORK / REFERENCES

Future studies could explore the long-term effectiveness of these methods under various environmental conditions, their scalability for large mining operations, and their economic feasibility for extracting valuable metals.