UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Design of an Acid Mine Drainage Remediation Process using By-products from the Steel Manufacturing and Sugar Processing Industries

Chemical Engineering Doctoral Dissertation

Prepared by:
Tamlyn Sasha Naidu
457495

Submitted to:
SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT, UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG, SOUTH AFRICA

Supervisors:
PROF. CRAIG SHERIDAN & PROF LIZELLE VAN DYK

January 2023

Abstract

Acid mine drainage (AMD) and basic oxygen furnace (BOF) steel slag are waste products from the mining and steel refining processes that are produced in large volumes throughout the world. Although both substances possess useful characteristics, they are largely treated as wastes, and dumped or disposed of in waterways and landfills, causing detrimental environmental and health issues. Treatment schemes that have aimed to address the occurrence or presence of AMD, in particular, are limited due to (i) the high cost of remediation (when compared to the relatively low cost of water), and (ii) variation in AMD characteristics which makes a standard/uniform treatment approach difficult to achieve. The technology explored within this dissertation has the potential to combat both challenges: (i) the cost of the treatment scheme would be substantially lower due to very little envisioned operational involvement, as well as the cost of reagents being kept low (through the use of waste and by products, and through potential valorisation of these wastes); (ii) the technology is aimed to be deployed at the source of production – individual mining sites – in a modular manner, allowing for alteration of treatment schemes to combat a wide variety of AMD strengths and qualities.

BOF slag and AMD combined in an optimized process allowed for the rise in pH of the AMD to neutral levels, as well as the removal of substantial amounts of metals and sulfates. Following this initial physical and chemical treatment, the partially treated AMD stream was then suitable for biological treatment using by-products from the sugar industry, allowing for further removal of sulfate, bringing the water closer to discharge and even drinking water limits: at a laboratory scale, sulfate was shown to reach levels of below 200 mg/L and levels of below 10 mg/L were reached for Al, Fe, Mg and Mn. Operation of a pilot-scale plant treating 200-1000 L/day demonstrated Al, Fe, Mn and SO_4^{2-} removals of 97%, 87%, 100%, and 87% respectively – showing that treatment occurred even in fluctuating AMD conditions. The configuration of the treatment scheme that yielded the best results was suggested for the final design and included a modular system in which BOF slag was used to increase the pH of the system before bacteria sugarcane derivatives were used to polish the sulfate leftover in the stream to below 400 mg/L.

The system which was proposed, designed and tested in this study was successful in treating AMD. It proved to be able to serve as a precursor to multiple other treatment regimes (reverse osmosis, membrane filtration, ionic exchange), or as a stand-alone system to service smaller, isolated areas that aim to reuse the AMD affected water in processes or for irrigation.