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Characterisation of precipitates formed in anaerobic and aerobic units designed to treat acid mine drainage from an abandoned coal mine in Carolina, Mpumalanga (South Africa)

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To contribute towards development of sustainable mine water management solutions in South Africa, a pilot passive treatment plant consisting of integrated anaerobic and aerobic units has been constructed to treat 1440 litres of acid mine drainage per day from an abandoned underground coal mine. The anaerobic unit used is a Reducing Alkalinity Producing System (RAPS), which combines the mechanisms of anaerobic treatment wetlands and anoxic limestone drains [1]. Aerobic units consisted of an oxidizing pond and a cascading trench. The pilot plant has been in operation for 12 months, and has successfully neutralized the water and completely removed contaminants, such as Fe, Al, Co, Zn, Ni, As, Pb, V, but with minimal SO₄ reduction (only 30% removal rate was achieved).

This study involved geochemical and mineralogical characterisation of precipitates formed in the anaerobic (RAPS) and aerobic (Oxidizing) units of the pilot passive treatment plant. Samples were collected from the top and bottom of the units and were analysed by means of XRF for metal loadings, as well as XRD and SEM for mineralogical analysis.

Metals such as Fe, Zn, Ni, Co and Cu precipitates as sulphides in the RAPS unit and this is attributed to microbial sulphate reduction. Concentrations of these trace metals increase from the top to the bottom of the anaerobic units i.e. 33 – 8,839.00 mg/kg; 13 – 1,717.00 mg/kg; 7.6 – 1,569.00 and 102 – 118 mg/kg for Zn, Ni, Co and Cu respectively. Metals, such as Co, Ni and Zn also precipitate in the aerobic units (oxidation pond), and this is likely to be due to sorption/co-precipitation with hydroxides of Fe. Their concentration also increase with depth (from top to bottom) i.e. <1 – 12 mg/kg; 4.7 – 20 mg/kg; and 34 – 97 mg/kg for Co, Ni and Zn respectively.

Fe and Al precipitates as hydroxides in the aerobic units and at the top layer of the RAPS unit, and this is attributed to oxidation and hydrolysis processes. Fe concentration decreases from top to bottom and this can be attributed to decrease in oxygen ingress or oxidation rates with depth i.e. 78.10 – 65.08 wt%; 62.48 – 13.09 wt% and 54.46 – 28.52 wt% in aerobic and RAPS unit respectively. Al precipitates increase with depth and is dependant on pH i.e. 0.96 – 37.58 wt% and 11.35 – 18.30 wt%; 0.52 – 0.82wt% for RAPS and aerobic units respectively. Based on XRD and SEM, common Fe hydroxides species include: jarosite (KFe₃(SO₄)₂(OH)₆); schwertmannite (Fe₁₆O₁₆(OH)_y(SO₄)_z.nH₂O); goethite (FeOOH); ferrihydrite (Fe(OH)₃). These Fe hydroxides are known to be excellent sorbents of trace metals, such as Co, Ni, and Zn) and subsequently can control their mobility, fate and transport in the environment [2,3]. Accumulation of these mineral/metal species in the passive treatment units presents an opportunity to recover valuable products that can offset the cost of remediation.

The study has enabled the development of predictive models for type of precipitates that are likely to form in the passive treatment units, taking into considerations their environmental implications and economic potential.

References:

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