Validating WRD conceptual models and implications for mine closure in semi arid environments: a high level assessment using field data

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Abstract

The prediction of how waste materials will evolve geochemically within waste storage facilities in semi arid environments requires a coherent and detailed understanding of the mechanisms that control oxidation reactions, and seepage generation. As part of a large scale investigation to improve the understanding of waste rock geochemistry at macro scale in semi arid environments O'Kane Consultants (OKC) has had the opportunity to lead two large scale waste rock storage facilities (WRSF) drilling programs at different sites in Western Australia. A range of WRSFs were investigated to include both active facilities and historical closed facilities of around 10-30 years in age. These investigations included approximately 2,000 m of sonic drilling, the recovery and detailed analysis of over 2,000 samples of core material and the installation of over 200 sensors at depths between 5 and 140 m within the waste which have provided over 5 million points of monitoring data to date and are still actively generating data.

The quantity and quality of materials testing and in situ monitoring data collected has provided OKC the opportunity to determine the specific factors related to in situ field conditions that act as the main controls on geochemical evolution of waste materials in semi arid environments. Data has been used to develop a detailed conceptual model for the geohydrology of WRDs within a semi arid environment. In addition OKC has developed field calibrated analytical AMD loading models.

The extensive data gathered as part of the assessment has allowed OKC to determine the geochemical, hydrological and geophysical evolution of the waste rock facilities as a result of 10-30 years of exposure. This valuable site data has been used to both back test the results of predictive models made for the waste facilities, and to optimise predictive models for future scenarios.

Key words: Semi arid environment, pyrite oxidation rate, stored acidity

Introduction

A typical conceptual model for oxygen ingress is that gas flux occurs as a result of air ingress occurring through the WRD at the bottom of the pile in rubble zones, and moving upwards through the free draining coarse material layers by the process of thermal advection. The conceptual model for the hydrology of waste rock dumps is that the infiltration of water enters the WRD at the top of the pile, percolating down through areas of fine grained materials due to their ability to retain water and the low air entry value of course grained material. During heavy rain events such as cyclones, water will also enter the WRD in coarse grained sections quickly percolating to depth.

On a conceptual level this kind of understanding of internal waste rock dynamics can be easily determined, the challenge is to take this conceptual understanding and make quantitative predictions about the geochemical and geo-hydrological evolution of the WRFS over time and understand AMD risk.

As part of a large scale investigation (Pearce and Barteaux 2014, 2014b) to improve the understanding of waste rock geochemistry at macro scale in semi arid environments O'Kane Consultants (OKC) has had the opportunity to lead two large scale WRSF drilling programs at different sites in Western Australia. A range of WRSFs were investigated to include both active facilities and historical closed facilities of around 10-30 years in age. These investigations included approximately 2,000 m of sonic drilling, the recovery and detailed analysis of over 2,000 samples of core material and the installation of over 200 sensors at depths between 5 and140 m within the waste which have provided over 5 million points of monitoring data to date and are still actively generating data.

Key findings from the data analysis and modelling have been summarised herein

Moisture cycling

Matric potential and temperature sensor data indicates that significant moisture cycling through the waste rock dumps occurs as a result of advection forced drying. The process results in transfer of oxygen and moisture through waste dumps in the vapour phase that stimulates oxidation reactions in material buried deep within the waste dump that would be considered as being “oxygen and moisture limited” based on theoretical understanding of waste dump geohydrology. Up to 100mm per year of net percolation may be redistributed as a result of this process.

A key consequence of advective drying is to significantly increase theoretical timeframes for “wetting up” of waste rock to occur as the overall water balance for the WRD is significantly impacted by this process that is not commonly included as part of traditional water balance calculations. In addition wetting up has been shown to not be a homogeneous process so the concept of a defined “wetting front” is not supported, rather preferential flow and drying occurs through the waste even after 30+ years of exposure.

Oxygen ingress

Air flow rates calculated based on site data indicate that where coarse basal zones are present air flux rates through waste mass of around 1–2 × 10^{-4} m^3/m^2s can be expected. Based on typical sulphide oxidation rates the oxygen flux that derived from gas flux of this magnitude is sufficient to allow oxidation to occur at unconstrained rates (Pearce et al 2015). Advective airflow rates through the waste are the primary control on oxidation rates for sulfides. This process has been linked to waste dump structure with basal rubble zones providing significant sources of continued oxygen ingress. In many cases due to segregation of waste as a result of end tipped structures, oxygen ingress is significant through the entire profile of the waste and oxygen ingress through the base is linked to internal flow pathways.

Given the above observations it may be inferred that oxidation reactions within the WRDs studied may not be O_2 limited, but are more likely to be limited by the supply and movement of H_2O. Geochemical analysis of drill core supports this conjecture as there is a significant presence of secondary sulfate minerals which are indicative of precipitation of sulfate bearing minerals as a result of stationary pore fluids (and therefore a very low L:S ratios). The geochemical system can therefore be best thought of as semi closed in that oxygen and H_2O (possibly supplied from internal evaporation rather than matrix pore water flow) can enter the waste but very limited leachate leaves the system. This results in a buildup of secondary sulfate minerals.

It is interesting to note that even with the very low L:S ratios observed in the WRSFs that oxidation reactions have proceeded to 60% or greater completion over 30 years (Pearce el 2015).

Predictive modeling

Based on the field investigation and ongoing monitoring data from the instruments placed within the waste a predictive model was established to determine the potential AMD discharge profile for the waste (Pearce et al 2015). The majority of acidity production is stored as secondary mineral products over the first 40 years of the assessment period and so is not likely to be reported in basal seepages. After 40 years however significant impacts on seepage quality are noted as both seepage rates increase as a result of “wetting up” and stored acidity products are released (Figure 1).

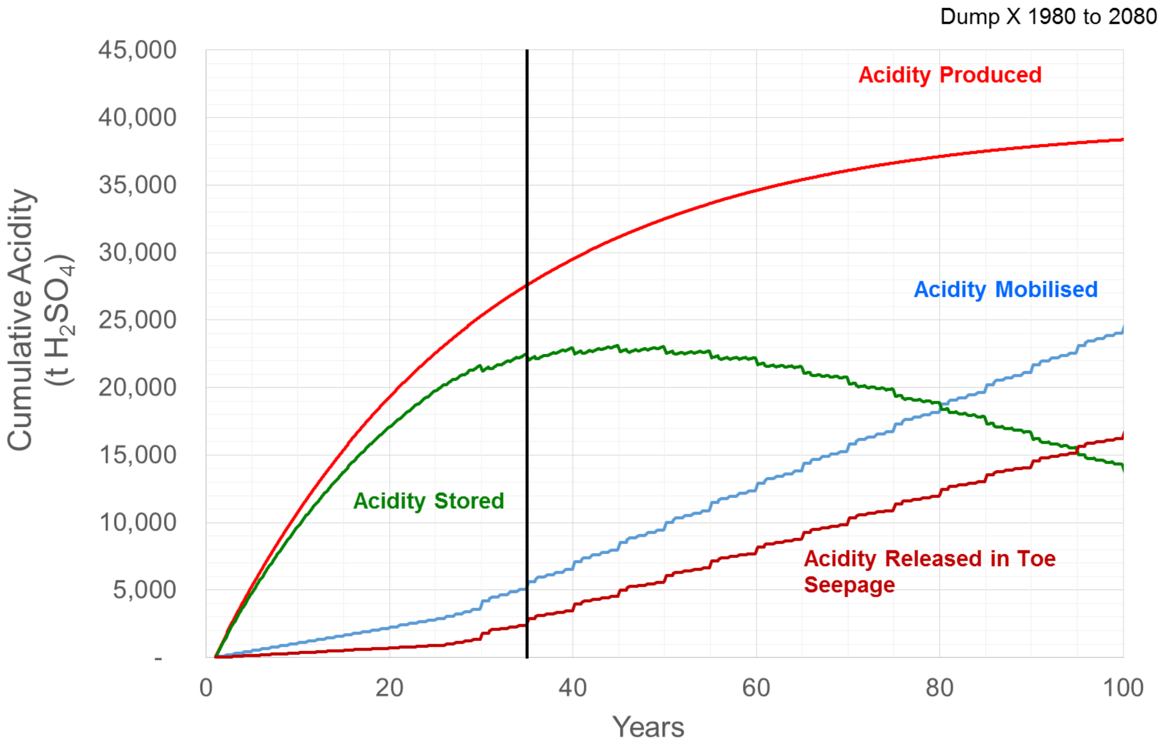

Figure 1 *AMD load predicted from field calibrated model*

Conclusions

In semi arid climates such as the Pilbara, low rainfall environments create conditions of very low liquid to solid ratios where high levels of oxygen ingress are indicated to occur. Field data from a number of historical WRD containing pyritic material indicates internally the waste materials have not reached a "wetted up" state even after 30 years of storage. However even in such low moisture environment oxidation reactions have proceeded to 60% or greater completion indicating that water supply is not an overriding oxidation reaction limiting factor. Air flux rates are indicated to be significant as a result of large advective gas fluxes resulting from the unsaturated nature of the material and large temperature gradients. The field data indicates that in semi arid environments limited seepages are likely to occur in the short term (<30 years) due to the low amount of net percolation occurring and high moisture losses from the WRD as a result of evapotranspiration from the surface and advective drying at depth.

An AMD load model built on conceptual model formed from the field data gathered indicates that in semi arid environments stored acidity loads are likely be generated a relatively high rates only limited by oxygen ingress rates for periods of up for decades. Over this timeframe significant pore water flushing and vertical drainage through the waste (and production of seepages) are not likely to occur and so >60% of the AMD is stored as semi volatile acid salts within pore spaces. Once "wetting up" conditions are reached and seepages begin, AMD loads are likely to be significant as the dissolution of the stored products will be at low L:S ratios and concentrations will be close to solubility constraints for key metals and sulfate.

It is notable that the lack of AMD seepages from waste dumps in semi arid environments is often used as proof that AMD is risks are limited, and that cover systems are an appropriate risk mitigation measure. However the implications of the work presented in this study extend to a significant reappraisal of the potential AMD risks of reactive waste rock stored in semi arid environments, and further to the effectiveness of cover systems as a "panacea" to manage AMD risks in these environments.

References

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