

Store and release cover systems: A suitable preventive for acid mine drainage in semi-arid monsoonal Queensland?

Anne Schneider^A, Thomas Baumgartl^A, David Doley^A and David Mulligan^A

^ASustainable Minerals Institute, The University of Queensland, Brisbane, QLD, Australia, Email a.schneider@cmlr.uq.edu.au

Abstract

Metalliferous mining operations are required to prevent contamination of the surrounding environment resulting from the discharge of leachates from waste repositories that may contain acid-forming sulfidic rocks or mine tailings. Waste rock cover systems are commonly used to isolate hazardous wastes from precipitation and thereby to prevent toxic or acidic mine drainage. Store and release cover systems are designed to retain all precipitated water within benign material overlying the waste, where the water is removed by evapotranspiration. Two cover designs were tested in semiarid monsoonal northwest Queensland: (1) 1.5 m of unconsolidated waste rock overlying 0.5 m of consolidated waste rock and (2) 2.0 m of unconsolidated benign waste rock. Cover performance was monitored with lysimeters, soil moisture and soil suction sensors. In a wet season with higher than usual precipitation (900 mm), water infiltration into underlying waste rock beneath bare covers varied from 3% to 76% of precipitation.

Key Words

Lysimeter, store and release cover, waste rock, drainage.

Introduction

Mining activities often result in the production of hazardous or potentially hazardous wastes such as waste rock from the mining operation and fine-grained wastes from minerals processing (tailings). Weathering of sulfidic waste rock in contact with water and oxygen can produce acid and metalliferous drainage and tailings often also contain a high levels of heavy metals or are sulfidic (Lottermoser 2007). Infiltration of precipitation into the waste material can result in the leaching of hazardous substances into adjacent environments. For mine lease relinquishment, mining companies are required to prevent any potential contamination of the surrounding landscape. In semi-arid environments, it is often proposed to use store and release cover systems (SRC) to enclose such hazardous wastes (Fourie and Tibbett 2007; Hauser *et al.* 2001). On mine sites, cover systems generally consist of benign (non-hazardous or non-acid-forming) waste rock which encapsulates waste rock dumps or tailings facilities. The thickness of the benign waste rock layer is designed according to site characteristics, climate (especially rainfall) and particle size distribution of the cover material. Other design features may include a compacted layer directly overlying the hazardous waste. The aim of a SRC system is to store precipitation in the benign waste rock and therefore prevent it from (deep) drainage and reacting with the hazardous waste. Stored rainwater is removed from the cover through evaporation and transpiration (O'Kane Consultants Inc. 2004). The theory of SRC systems is based on the water balance equation (Eq. 1)

$$L=P-Q-\Delta S-(EV+T) \quad (1)$$

Where L = seepage, P = precipitation, Q = runoff, ΔS = change in moisture content of the cover material, EV = evaporation and T = transpiration.

The objective of this paper is to investigate the feasibility of a bare SRC system for acid drainage prevention in a region with distinct wet and dry seasons in semi-arid monsoonal north-west Queensland, Australia.

Method

Field site

The mine site is located in a region classified as *BSh* (B = arid, S = steppe, h = hot arid) in the Köppen and Geiger Classification (Kottek *et al.* 2006). The mean monthly minimum and maximum temperatures are 11.6 and 37.3°C, respectively. The long-term annual rainfall of the area is 420 mm, but rainfall is highly erratic. Over 77 years of records, annual rainfall fluctuated between 104.9 mm in 1970 and 870.7 mm in 1950. Three-quarters of the annual precipitation occurs in the southern hemisphere summer, mainly between December and March but this is highly variable, from 78.0 mm in 1985/86 to 798.3 mm in 1996/1997, respectively. Most summer rainfall events are high intensity storms although the long-term data do not record these intensities (Bureau of Meteorology 2009a).

Cover trials

Two cover trial areas (20 m x 60m) were constructed in October 2008 with a supplemental installation of sensors in December 2008. The cover designs were: (1) 0.5 m compacted benign waste rock on the potentially acid-forming waste rock, overlaid by 1.5 m uncompacted benign waste rock (Treatment 1V) and (2) 2.0 m uncompacted benign waste rock placed directly on potentially acid-forming waste rock (2V). Each cover trial area was subdivided into three subplots (20 m x 20 m) and instrumented identically. In each subplot, a lysimeter (3 m diameter and 3 m deep) was placed into the hazardous waste material with its top being level with the surface of that material. Each lysimeter was connected to a tipping bucket gauge through a PVC pipe with a slope of ca. 2%. Furthermore, 16 soil matric potential sensors (229-L, Campbell Scientific, Logan UT USA) and 6 soil moisture sensors (Model CS616, Campbell Scientific, Logan UT USA) were installed in a single vertical line extending from the base of each lysimeter to the top of the cover system. A standard automatic weather station (Campbell Scientific, Logan UT USA) was mounted nearby.

Results

The data presented focuses on subplots 1Vb, 1Vc, 2Va and 2Vc based on integrity of the underlying data set.

Precipitation

The main period of precipitation in the wet season 2008/2009 began in the first week of December 2008 and ended in the second week of February 2009. No significant precipitation was received in March 2009. In total, 916 mm of rainfall was measured at the experimental site in an interval of 67 days. This rainfall was greater than that at the Bureau of Meteorology (BoM) station in the vicinity of the trials, which recorded 668mm of rainfall for the same period. The BoM rainfall for January 2009 was the highest and the 2008/2009 wet season was the third wettest since measurements commenced at the site in 1932 (Bureau of Meteorology 2009b).

Soil suction

The soil suction sensors responded quickly to rainfall events and the advance of the wetting front. The first major rain event on the 7th of December (27mm) triggered slightly different reactions on the subplots. Infiltration of rainfall proceeded approximately to the same depth on 2V (2Va: 1.02 m, 2Vc: 1.10 m) (Figure 1c, d). However, on Treatment 1V, infiltration was measured from 1.10 m (1Vc) to 1.99 m (1Vb), which indicates highly heterogeneous pore size distribution at this cover trial (Figure 1 a, b). The suction values clearly show that in all four subplots, rainfall infiltrated into the hazardous waste. On Treatment 1Vb this occurred after 151 mm cumulative rainfall (Figure 1a), whereas on Treatment 1Vc infiltration into the potentially acid-forming material first occurred after only 99 mm of cumulative rainfall (Figure 1b). On 2V, water reached the hazardous material after 108 mm and 140 mm cumulative rainfall in Treatments 2Vc and 2Va, respectively (Figure 1c, d). Beneficial influences of cover design, i.e. the compacted layer, on the hydrology of these cover systems cannot be claimed on the basis of the existing data.

Seepage

Seepage was recorded in all plots but the amount of seepage and time of occurrence varied between the subplots. No seepage was recorded from any plot between 13/01 and 24/01/2009. In these 10 days, a total of 253 mm of rainfall was recorded, with storm events of 37 mm, 48 mm and 50 mm on the 20th, 21st and 22nd of January, respectively. As the soil suction and soil moisture sensors were operating satisfactorily during this period, it is likely that tipping buckets were not functioning correctly during that time. Cumulative seepage rates range from 21 mm (2Va) up to 736 mm (1Vc) (Figure 2). Generally seepage from the covers with a 0.5 m compacted layer was higher than from the plots without a compaction zone. However the differences within the cover designs themselves are very pronounced. Approximately 310 mm more drainage was recorded at 1Vc compared with 1Vb, and at 2V the difference in drainage from the two lysimeters was almost 200 mm. From the four subplots under consideration, only 2Va showed drainage from the lysimeter of less than 5% of rainfall. The amount of water seeping out of the remaining three plots exceeded this acceptable threshold by a large margin.

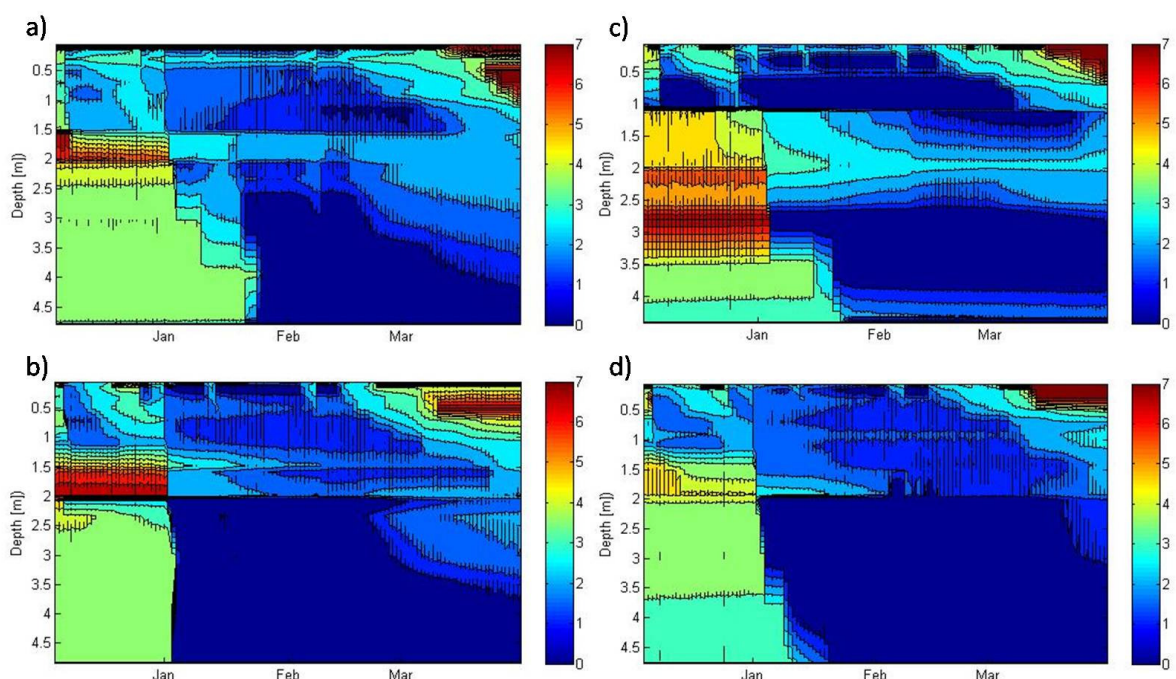


Figure 1. Logarithmic soil suction [hPa] over the course of the wet season 2008/2009 on subplots a) 1Vb, b) 1Vc, c) 2Va and d) 2Vc.

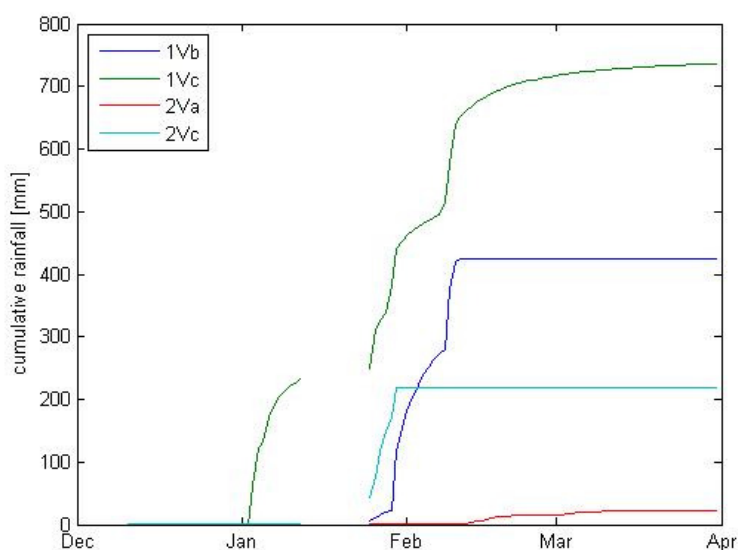


Figure 2. Cumulative seepage [mm] over the course of the wet season 2008/2009 on subplots 1Vb, 1Vc, 2Va and 2Vc.

Conclusion

In a wetter than normal wet season in north-west Queensland, seepage under a bare (non-vegetated) 2 m cover system can reach up to 76% of the 916 mm of rainfall received during the period under consideration. The importance of vegetation for the mitigation of seepage amounts has been stressed by several authors (Hauser *et al.* 2001; O'Kane Consultants Inc. 2004; O'Kane and Wels 2003). The presence of vegetation can enhance the storage capacity of a cover as more water is removed from the cover through evapotranspiration than by evaporation alone. However, the frequency and intensity of storm events in areas with distinct wet and dry seasons remain a challenge for SRC systems. If the rain patterns and extreme events of a region and the hydraulic properties of potential cover material are known, as well as the potential for the plant community to remove water from the cover, the maximal seepage rates through a cover can be estimated and a decision made on the suitability of a SRC for the region.

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