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A Case Study Revisited of Full-Scale ARD from a Waste-Rock Pile with Abundant Reactive Neutralization Potential

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Abstract

An old case study included more than 8000 in-field measurements of rinse (non-pulverized) pH in a full-scale waste-rock pile with pH 3 ARD drainage. These measurements were taken as the pile was excavated, relocated, and submerged in a nearby lake. The rinse-pH values had been previously shown as time series, confirming that portions of the pile were acidic and portions still contained reactive Neutralization Potential (NP).

This revisitation of that old case study focussed on spatial distributions of rinse pH taken from (a) the top, middle, and bottom of the outer few meters of the exposed slope and (b) vertically integrated samples of the inner waste rock.

New observations include:

- Of the 1146 outer-slope samples, 61% were acidic, and 39% were near neutral, despite ARD drainage at pH 3. In contrast, of the 7168 inner waste-rock samples, 28% were acidic and 72% were near neutral, despite ARD drainage at pH 3. Thus, large portions of the pile were still near neutral. Overall, two-thirds of the rock samples were neutral despite ARD.

- Rinse pH values below 3 were rare and values above 6 were common. As a result, the ARD drainage pH of 3 was not an equivalent mixture of acidic and neutral flowpaths, but indicated flow likely followed preferential flowpaths through the acidic pathways.

- For the outer slope of rock, about 46% of the vertical profiles were consistently acidic from top to bottom, and thus acidic conditions were generally continuous vertically in roughly half the outer slope. The next highest category, at 24% of profiles, was all near neutral from top to bottom. Thus, near-neutral conditions were generally continuous vertically in roughly a quarter of the outer slope. The remaining profiles showed a bias towards acidic conditions at the bottom rather than top of the rock.

- The inner waste rock was more near neutral volumetrically, but, in some acidic locations, more intensively acidic.

1. Introduction

The now-closed Eskay Creek Minesite is located in a relatively wet portion of British Columbia, Canada, at relatively high elevation (~900 m) with nearby alpine terrain. It was a relatively small, high-grade underground mine.

Its waste-rock dump, built in the early 1990's, was elongated in the northeast-southwest direction. The footprint of the dump was irregular, but was approximately 350 m by an average of 80 m, with an approximate maximum height of roughly 4 m. It contained roughly 100,000 tonnes of rock.

This waste rock was placed beside a creek or "meltwater channel". With flows up to 8000 L/min, creek water occasionally flowed into and through the waste rock, aiding the flushing and transport of acidity and metals.

From 1990 to the summer of 1991, the dump drainage was neutral. However, in the fall of 1991, as precipitation increased and flows from the adjacent creek began increasing, pH reportedly began fluctuating between 7 and 3. No correlation was noted between pH and flow. By winter of 1991, drainage pH from the dump had reportedly stabilized and remained around 3. Collection and treatment of the acidic drainage were then implemented using NaOH.

Mass-balance calculations showed that only roughly 10-20% of total Neutralization Potential (NP) was consumed before acidic drainage appeared within two years of first rock dumping. Thus, a significant amount of NP remained within the dump. However, it was not initially clear whether the NP was encapsulated or otherwise inactivated, or still reactive. Also, two independent mass-balance calculations for acidity in the dump provided similar estimates of acid generation: 220 and 530 t/yr.

In 1994, Eskay Creek made an innovative decision to relocate and submerge this waste rock in nearby Albino Lake (e.g., Figures 1-1 and 1-2). Although the disassembly and relocation were relatively expensive, the long-term savings outweighed the cost of long-term ARD treatment.

Disassembly of the Eskay Creek dump began in 1994, when the outer slope of the waste-rock pile was transported by dump truck to the nearby lake. Due to concerns over retained acidity in the waste rock being released into the lake, lime was added to individual loads of waste rock to neutralize it. The amount of added lime was empirically estimated from regularly measured rinse pH values from samples in large buckets. These samples were collected from the top, middle, and bottom of the excavated outer slope. Initially, too much lime was added in 1994 and lakewater pH became alkaline, so lime addition was reduced until neutral pH was restored and maintained. Only an estimated 3000-4000 t, from the outer few meters of the slope, was moved to the lake in 1994.

In 1995, disassembly resumed in early May and continued until August. A combined total of approximately 100,000 t of waste rock was excavated in 1994 and 1995.

This information and more were compiled into a 400-page Canadian MEND report (Morin et al., 1997). Selected details were published in Morin and Hutt (1997a, 1999, 2000, 2001a, and 2001b).

Figure 1-1. Photograph of the ongoing excavation of the ARD-releasing waste-rock pile at the Eskay Creek Minesite.

Figure 1-2. Photograph of the relocation and submergence of ARD-releasing waste rock shown in Figure 1-1.

2. Waste-Rock Rinse pH Revisited

The objective of this MDAG case study is to re-examine the values of rinse pH, measured as each load of waste rock was excavated from the receding, remaining slope. In past publications, the rinse-pH data were shown as time series (Figures 2-1 and 2-2). Because the pH values were rinse (non-pulverized), rather than paste (pulverized), measurements, the time series confirmed that abundant, reactive NP was still present in the waste-rock pile, despite the acidic pH 3 drainage. This was in contrast to other sites, where NP was encapsulated with secondary-mineral precipitants and thus rendered unreactive (e.g., Morin and Hutt, 2008), or NP-bearing materials were bypassed (Morin and Hutt, 1997b).

What is not readily apparent in the time series of Figures 2-1 and 2-2 are interesting rinse-pH differences (a) among the top, middle, and bottom of the outer slope (Section 2.1) and (b) between the outer slope and inner waste rock (Section 2.2). While some differences likely lay in the various rock units, their layering, their hydraulic conductivity, and their ABA characteristics (Morin et al., 1997), the primary interest here is the spatial distribution of pH-neutral rock in a waste-rock pile actively releasing ARD at pH 3.

2.1 Rinse pH from the Top, Middle, and Bottom of the Outer Slope

Histograms of rinse pH from the outer few meters of the waste-rock slope, at the top, middle, and bottom levels of each cut, display similar patterns (Figures 2-3 to 2-5), with a wide range of values at each level. However, the histogram for the top samples (Figure 2-3) does not show the prominent peak between pH 4 and 5. These are also shown as percentages of samples along the y-axis of Figure 2-1.

Notably, all three levels produced few rinse-pH values less than 3, the pH of the overall drainage from the waste rock. This suggests most flow passed through the pH 3-4 rock and relatively little through the more neutral portions; otherwise, the net pH would have been greater than 4. The inner waste rock generally supports this (Section 2.2).

Of the 1146 outer-slope samples, 700 (61%) were acidic, defined here as rinse pH < 6.0. Thus, 446 samples (39%) were near neutral, despite ARD drainage at pH 3.

Along each of the 382 vertical profiles in the outer slope, the three samples could be classified as all acidic, all near neutral, acidic at the top and middle, etc. This showed that about 46% of 382 vertical profiles were consistently acidic from top to bottom (Figure 2-6). Thus, acidic conditions were generally continuous vertically in roughly half the outer slope.

The next highest category, at 24% of profiles, was all near neutral from top to bottom. Thus, near-neutral conditions were generally continuous vertically in roughly a quarter of the outer slope.

The remaining categories showed a significant grouping of 79 profiles (21%) that were acidic at the bottom (with and without the middle or top also being acidic). This showed some bias towards acidic conditions at the base of the outer slope, as only 10% of profiles had acidic rock overlying near-neutral rock. This enhancement is consisted with ARD flowing through the base (Section 1) and relatively impermeable rock on top (Morin et al., 1997).

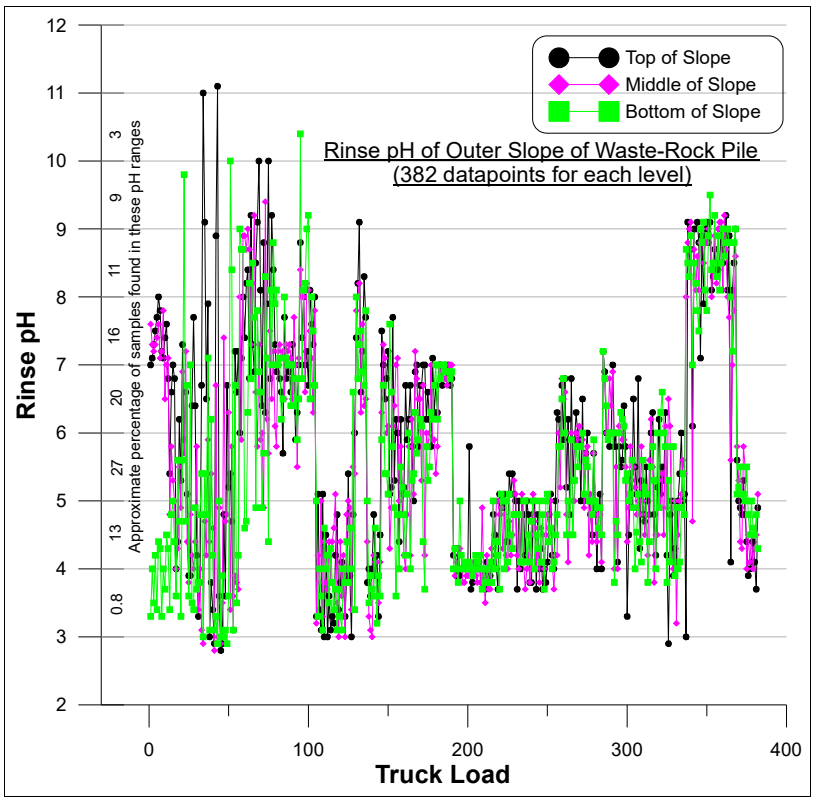

Figure 2-1. Time series of rinse pH from the top, middle, and bottom of the outer slope of the waste-rock pile as a small portion was excavated during the first year.

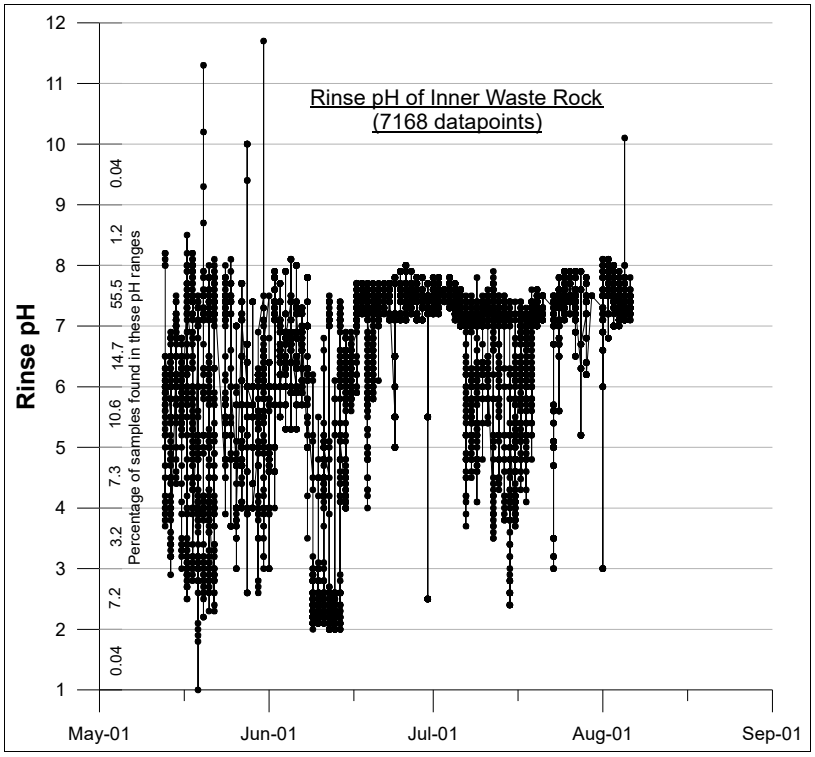

Figure 2-2. Time series of the vertically integrated rinse pH from the inner waste-rock pile as most was excavated during the second year.

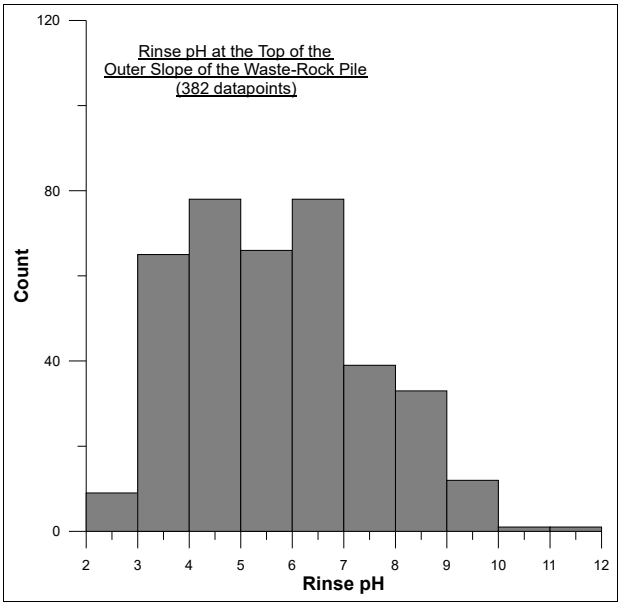

Figure 2-3. Histogram of rinse pH from the top of the outer slope of the waste-rock pile.

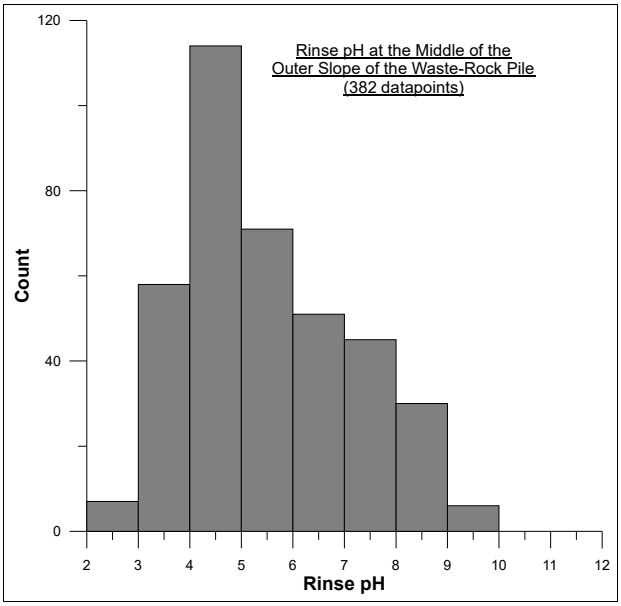

Figure 2-4. Histogram of rinse pH from the middle of the outer slope of the waste-rock pile.

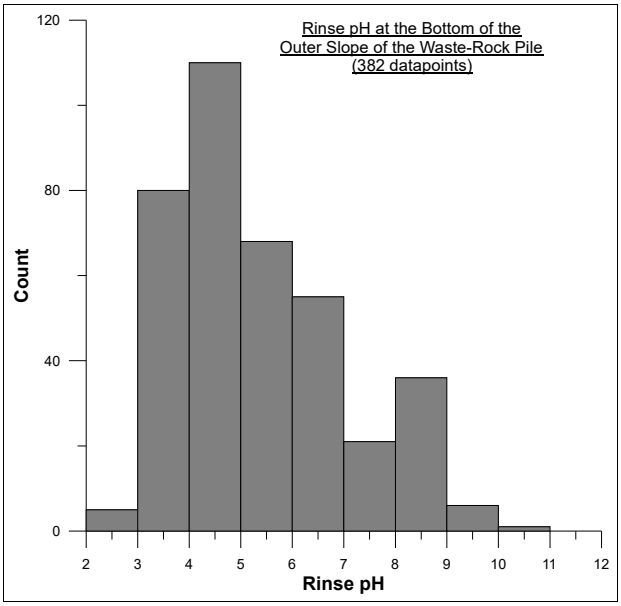

Figure 2-5. Histogram of rinse pH from the bottom of the outer slope of the waste-rock pile.

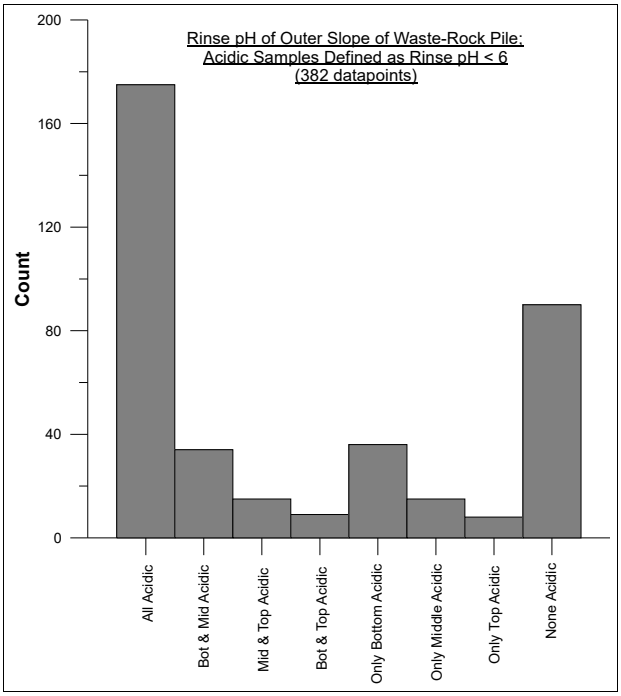

Figure 2-6. Histogram of the numbers and locations of acidic samples along each vertical profile in the waste-rock pile.

2.2 Rinse pH from Vertically Integrated Profiles of the Inner Waste Rock

Only a few meters of the outer slope were excavated in the first year (Section 2.1), with most waste rock excavated in the second. Rinse pH of this "inner" waste rock was measured on vertically integrated profiles, with 7168 values collected (Figure 2-2).

Of the 7168 inner waste-rock samples, 2033 (28%) were acidic, defined here as rinse pH < 6.0. Thus, 5135 samples (72%) were near neutral, despite ARD drainage at pH 3.

The histogram of rinse pH for the inner waste rock (Figures 2-7 and 2-8) differed in two primary ways from those of the outer slope (Figures 2-3 to 2-5 and 2-8).

First, rather than the number of samples decreasing as rinse pH increased, most inner-rock profiles were near neutral. This meant most of the inner waste rock (72%) was pH neutral, whereas most of the outer slope (61%) was acidic.

Second, whereas rinse pH in the outer slope was rarely less than 3, rinse pH for the inner waste rock was between 2 and 3 more often than between 3 and 4.

Thus, the inner rock was more near neutral volumetrically, but, in places, more intensively acidic.

As with the outer slope (Section 2.1), the predominance of rinse pH values greater than 3, relative to ARD drainage pH around 3, means most flow passed through the most acidic rock and relatively little through the more neutral portions; otherwise, the net drainage pH would have been greater than 4. Such focussing of water flow into acidic layers has also been observed elsewhere (e.g., Morin and Hutt, 1997b).

3. Conclusion

Based on this revisitation of the old case study, new observations include:

- Of the 1146 outer-slope samples, 61% were acidic, and 39% were near neutral, despite ARD drainage at pH 3. In contrast, of the 7168 inner waste-rock samples, 28% were acidic and 72% were near neutral, despite ARD drainage at pH 3. Thus, large portions of the pile were still near neutral. Overall, two-thirds of the rock samples were neutral despite ARD.

- Rinse pH values below 3 were rare and values above 6 were common. As a result, the ARD drainage pH of 3 was not an equivalent mixture of acidic and neutral flowpaths, but indicated flow likely followed preferential flowpaths through the acidic pathways.

- For the outer slope of rock, about 46% of the vertical profiles were consistently acidic from top to bottom, and thus acidic conditions were generally continuous vertically in roughly half the outer slope. The next highest category, at 24% of profiles, was all near neutral from top to bottom. Thus, near-neutral conditions were generally continuous vertically in roughly a quarter of the outer slope. The remaining profiles showed a bias towards acidic conditions at the bottom rather than top of the rock.

- The inner waste rock was more near neutral volumetrically, but, in some acidic locations, more intensively acidic.

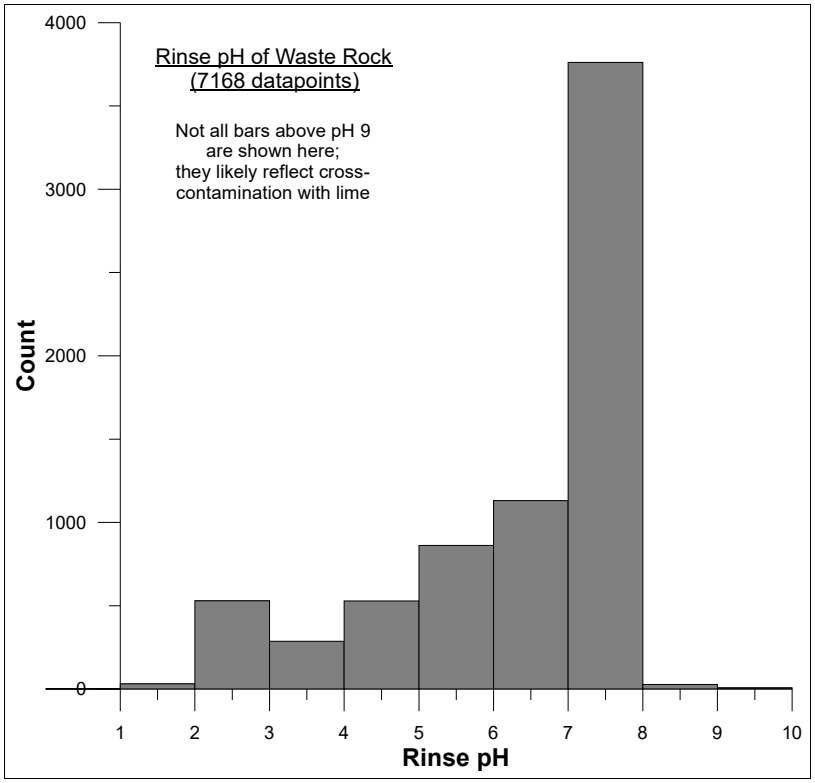

Figure 2-7. Histogram of rinse pH from vertically integrated samples of the inner rock of the waste-rock pile.

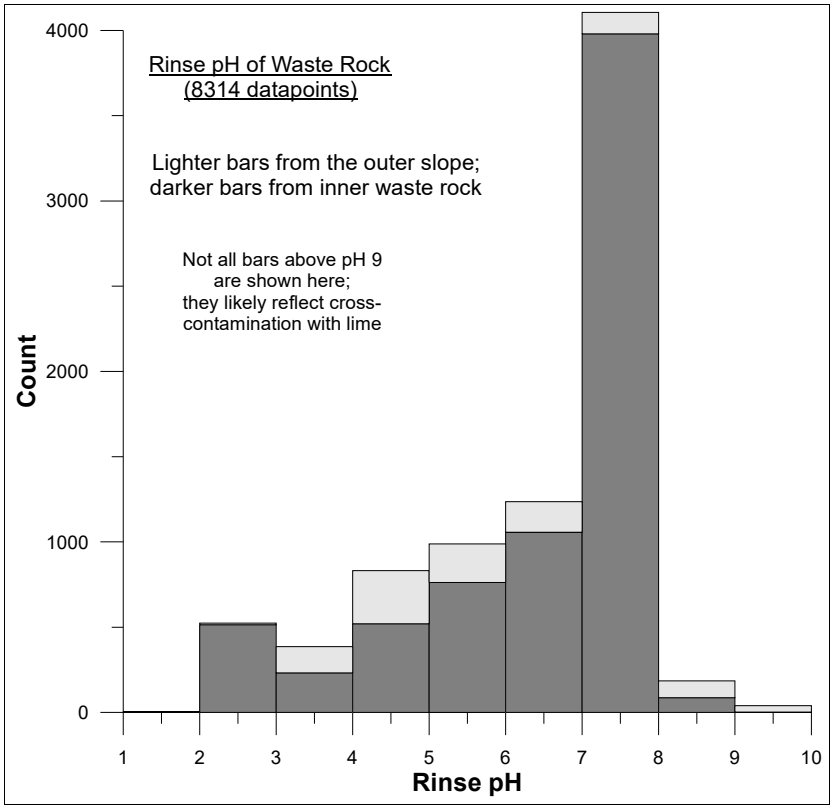

Figure 2-8. Stacked histogram of rinse pH from the outer slope and inner rock of the waste-rock pile.

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