REACTIVITY OF STOCKPILED MATERIAL AT MIDNITE MINE: A PRELIMINARY EVALUATION[1]

by P. B. Altringer[2] and L. J Froisland[3]

Abstract. The U.S. Bureau of Mines is investigating reactivity of stockpiled low-grade ore and waste rock at the Midnite Mine near Spokane, WA. Before reclamation options can be accepted for this mine site, reactivity of stockpiled materials must be ascertained to (1) determine isolation requirements for the low-grade ore and (2) ensure that runoff water from waste material used as cover during reclamation will not exceed contamination limits set forth in a National Pollution Discharge Elimination System (NPDES) permit. This determination is complicated by the fact that much of the waste rock contains sulfide minerals that will oxidize over time and release acid and/or metallic components into the ground water and/or surface waters. Reactivity, as defined in this study, is determined through percolation column leach tests using a simulated meteoric water leachant. This report describes results from preliminary tests with surface grab samples from various piles, which indicate that (1) low-grade ore is reactive and will require isolation from ground and surface water and (2) waste material needs further evaluation. A more systematic sampling program has been initiated to develop reactivity profiles of stockpiled waste materials on the site.

ADDITIONAL KEY WORDS: Reclamation, uranium mines, Washington State

Introduction

The Midnite Mine is an inactive uranium mine located on the Spokane Indian Reservation about 85 km northwest of Spokane, WA. Uranium was discovered on this site in the early 1950's, and mining began in the mid to late years of the same decade. Mining activity ceased in 1981; and, since that time, the mining company and several Government agencies have been involved in site reclamation.

The Midnite Mine is unusual among uranium mines in that the rock mineralogy includes several sulfides, which weather to form acid and have the potential to contaminate both ground water and surface waters. Water has accumulated in two open pits on the mine site, and water quality in the largest of these pits is poor. Several seeps have also been found downgradient from the mine site with poor quality water. Stockpiles of mine waste and low-grade uranium-bearing rock, which have been left exposed on the surface, are suspected sources of this water contamination.

The U.S. Bureau of Mines (Bureau), which is one of the Federal agencies involved at the Midnite

[1]Paper presented at 1993 National Meeting of the American Society for Surface Mining and Reclamation, Spokane, Washington, May 16-19, 1993.

[2]P. B. Altringer is a Group Supervisor at Salt Lake City Research Center, Bureau of Mines, U.S. Department of the Interior, Salt Lake City, UT 84108.

[3]L. J Froisland is a Chemical Engineer at Salt Lake City Research Center, Bureau of Mines, U.S. Department of the Interior, Salt Lake City, UT 84108.

Proceedings America Society of Mining and Reclamation, 1993 pp 489-504
DOI: 10.21000/JASMR93020489

https://doi.org/10.21000/JASMR93010489

Mine, has conducted investigations into several areas of the reclamation work: (1) processes for treatment of impounded water, (2) hydrology studies to determine ground-water quality and flow patterns across the site, (3) geophysical studies to aid in determining underground configurations within the mine site, and (4) reactive rock studies to determine the role of stockpiled waste rock and low-grade ore in water contamination. This paper describes Bureau work in reactive rock studies, work that has been carried out at the Salt Lake City Research Center.

Reactivity

Surface water leaving the Midnite Mine site discharges eventually into the Spokane River arm of Lake Roosevelt on the Columbia River. To prevent contamination of this important recreational facility, the U.S. Environmental Protection Agency (EPA) issued a permit to the mine operator under the National Pollution Discharge Elimination System (NPDES), which includes, among other items, metal-concentration and pH discharge limits for surface water at the point where the discharges leave the mine site (U.S. Environmental Protection Agency, 1986). Surface water leaves the mine site through three drainage channels known as East, Central, and West Drainages. NPDES limits are applied to a flow-proportioned volume of the total discharge from all three drainages. Because low-grade ore stockpiles and waste rock dumps are placed in all three drainage channels and have the possibility of contaminating all three flows, dilution of contaminant flow from any one drainage by clean water from the others is not probable. For the purposes of this report, the Bureau has defined "reactivity" as the potential for metals to leach from stockpiled rock in concentrations exceeding the NPDES permit limits. Metal-concentration and pH discharge limits are shown in table 1.

Before any reclamation option can be accepted for this mine site, reactivity of stockpiled materials must be ascertained to (1) determine isolation requirements for the low-grade ore and (2) ensure that runoff water from waste material used as cover during reclamation will not exceed contamination limits set forth in the NPDES permit. This determination is complicated by the fact that much of the waste rock contains sulfide minerals that will oxidize over time and release acid and/or other regulated elements into the ground water and/or surface waters. Rock leachability data are also useful in determining the origin of contaminants found in ground water migrating through the mine site and in water accumulating in the two open pits on the mine site.

Description and Analyses of Samples

The Bureau began the investigation of rock reactivity at the Midnite Mine site in 1988 by collecting several grab samples from low-grade ore piles. A second collection was made in 1989 with expanded areas of interest. All of these samples were analyzed for chemical and mineralogical content. Figure 1 is a computer-generated schematic of the Midnite Mine site, showing locations of the various ore stockpiles, waste dumps, and pits.

Sample Collection

In the fall of 1988, personnel from the Bureau and the Bureau of Indian Affairs (BIA) collected rock samples from several of the low-grade ore piles and from Pit 2, which was one of the early open pits and which has since been backfilled with waste rock from other pits. These samples were grab samples taken from the

Table 1. NPDES metal-concentration and pH limits for surface water discharge from Midnite Mine site

Effluent characteristic	Discharge limits	
	Daily maximum[1]	Daily average[2]
Ra^{226} (dissolved) . . . . . pCi/l . .	10.0	3.0
Ra^{226} (total) . . . . pCi/l . .	30.0	10.0
U (total) . . . . mg/L . .	4.0	2.0
Zn (total) . . . . mg/L . .	1.0	0.5
Mn (total) . . . . mg/L . .	10.0	3.0
pH . . . . Standard Units . .	6.0 - 9.0	
	1-hour average[3]	4-day average[4]
Cu (total recoverable) . . mg/L . .	0.096	0.055
Cd (total recoverable) . . mg/L . .	0.03	0.005

[1]Daily maximum is the maximum value measured on any day during the monitoring month.
[2]Daily average is determined by dividing sum of discharges by the number of days when discharge was monitored in any given month.
[3]1-hour average is determined by a grab sample analysis.
[4]4-day average is total units discharged during a 4-day period of operation divided by four.

surface of the piles. Following the 1988 sample collection and test program, the question remained if rock below the surface of the pile would have the same reactivity or potential for metal dissolution during precipitation events or snow melt as do surface materials. Bureau and BIA personnel returned to the mine site in 1989 to collect interior samples from piles that had shown high metal leaching in the first set of samples. Pit 2 and Ore Pile C were sampled in this 1989 collection by digging a trench into the piles with a backhoe; Ore Pile 3 was sampled by cutting a new roadway down the side. Grab samples were then collected from three levels of the trench walls or from the side of the roadway cut.

In addition to the ore pile samples, samples of waste material from a waste rock dump known as the Hillside Dump were collected in 1989. This dump was constructed with lifts about 7.5 m in height and has an overall height of approximately 61 m. Each lift face was sampled for soil pH using a soil paste method similar to the one described by Sobek, Schuller, Freeman, and Smith (1978), yielding a range of pH values from 3 to 7. Reactivity samples were collected from the top of the dump and from selected lifts to include samples with pH values over the measured range.

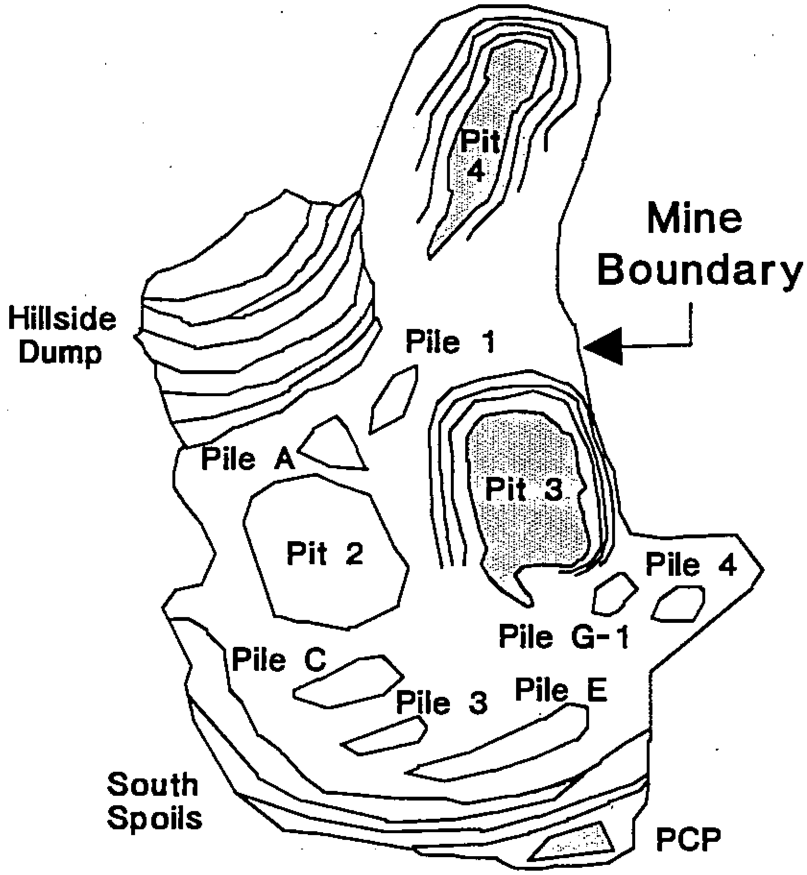

Figure 1. Schematic of Midnite Mine

Chemical Analyses

Grab samples collected from the various rock piles in 1988 and 1989 were crushed and sized to minus 4 plus 10 mesh for the column leach tests. Table 2 presents a listing of samples collected and uranium and manganese assays of the sized material. Uranium concentrations were determined by fluorometric methods and ranged from 7 ppm in the Pit 2 waste rock to over 1,000 ppm in the interior of Ore Pile 3. Manganese concentrations were determined by inductively coupled plasma (ICP) methods and ranged from <110 ppm on the top of Ore Pile G-1 to nearly 2,300 ppm in the interior of Ore Pile 3. Concentrations of other elements included in the NPDES discharge permit--copper, cadmium, and zinc--were mostly below detection limits for the ICP scans and so are not listed in the table. Radium was not analyzed because of the high cost of radium analyses.

Mineralogical Analyses

Crushed and blended reactive rock samples from the 1988 and 1989 Midnite Mine collections were submitted for mineralogical analysis. Mineralogical evaluation of 1989 samples showed the same general results as did evaluation of 1988 samples, which are shown below. Individual grains ranged in size from 1/2 to 5 mm. All samples were examined under the binocular microscope to determine the general

Table 2. Origin and year of rock samples and analyses of minus 4 plus 10 mesh size fraction

Origin of samples[1]	Uranium, ppm 1988	Uranium, ppm 1989	Manganese, ppm 1988	Manganese, ppm 1989
ACIDIC ORE PILES				
Ore Pile 1 (northwest side)	40	NS	230	NS
Ore Pile 1 (top)	70	NS	160	NS
Ore Pile 4 (south side)	170	NS	950	NS
Ore Pile 4 (southwest side)	140	NS	490	NS
Ore Pile C (north side)	500	NS	2240	NS
Ore Pile C (top)	NS	22	NS	870
Ore Pile C (1.5 m deep)	NS	55	NS	1430
Ore Pile C (2.7 m deep)	NS	47	NS	650
Ore Pile 3 (south side)	130	NS	1060	NS
Ore Pile 3 (top)	110	242	1100	1610
Ore Pile 3 (3 m deep)	NS	178	NS	990
Ore Pile 3 (4.6 m deep)	NS	1018	NS	2270
Ore Pile G-1 (south side)	70	NS	<110	NS
Ore Pile G-1 (southeast side) . . .	20	NS	550	NS
Ore Pile G-1 (top)	100	NS	<110	NS
ALKALINE ORE PILES				
Ore Pile A (north side)	190	NS	390	NS
Ore Pile E (high lime) (top) . . .	540	NS	1290	NS
WASTE ROCK PILES				
Pit 2 (southeast surface)	10	8	470	630
Pit 2 (1.2 m from surface)	NS	7	NS	550
Pit 2 (2.4 m from surface)	NS	34	NS	560
Hillside Dump (east end of top) . .	NS	74	NS	610
Hillside Dump (middle of top) . . .	NS	89	NS	570
Hillside Dump (west end of top) . .	NS	225	NS	720
Hillside Dump (pH 3 lift)	NS	9	NS	270
Hillside Dump (pH 6 lift)	NS	59	NS	790
Hillside Dump (pH 7 lift)	NS	59	NS	460

[1]1989 top and all 1988 samples were surface samples.

ND Not sampled that year.

rock type of various grains. All of the samples with the exception of Ore Pile E (high-lime) protore material were very similar in composition. Each sample contained the following rock types with various ratios between the samples: granite (including quartz, K-feldspar, plagioclase, pyroxene, amphibole, and mica); monzonite, which is similar to granite; mica schist, both muscovite and biotite varieties; amphibolite (a minor constituent); quartz; feldspar (partially weathered to clay); and calcite, which is a minor constituent in most ore piles except for Pile E. Pile E rock consists mainly of calcite with lesser amounts of K-feldspar, Ca-plagioclase, pyroxene, mica, wollastonite, and apatite. Some of the calcite grains contained numerous 2 to 20 micron size inclusions of a Ca, U silicate (uranophene).

Reactivity Test Description

The Bureau selected a percolation column leach system for reactivity testing of sized rock samples from various stockpiles on the site. This test system was judged to yield the best approximation of actual conditions existing in the stockpiles and dumps. Later work by other researchers confirmed this, and column leaching is one of the accepted methods in this country and in Canada for prediction of weathering and acid rock drainage (Coastech Research, 1990; Bradham and Carrucio, 1991). Rock samples collected in 1988 and 1989 were crushed and sized to minus 4 plus 10 mesh; and 750 g of sized rock were placed in 3.8-cm-ID by 61-cm-long columns, which are within the usual range of column sizes employed for this type of test (Coastech Research, 1990). Fine particles were removed to eliminate column plugging and channeling and to ensure oxygen contact with all parts of the column load during the test. Material at the mine varies in particle size from fine soil to huge boulders meaning that mine-site conditions will not be the same as those used in the laboratory although efforts were made to approximate atmospheric mine-site conditions as closely as possible.

Precipitation falling in the mine area had been collected and analyzed in 1984-85 and showed pH values as low as 4.5 (U.S. Geological Survey, 1989). Simulated rainwater was prepared in the laboratory for the percolation leach tests and adjusted to pH 4.2 to allow for "worst case" precipitation. Solution flow rate into the columns was 0.042 ml/min, which is equivalent to a constant precipitation rate of 5 cm/day. The 1988 rock samples were leached initially for 85 days after which the leachant pumps were turned off and the columns were opened to the atmosphere through vents in the top and bottom. Rock samples in the columns were allowed to dry under these conditions for 48 days after which the bottom vent was closed again and leaching resumed for 2 weeks to determine the effect of the dry period. The 1989 samples were treated similarly except that the initial leach period was reduced to 73 days to shorten the overall test period. Based on the estimated average annual precipitation at the Midnite Mine site of 38 cm during recent drought years, each column in the 1988 series received approximately 11.3 yr of precipitation in the first 85 days of testing; and each column in the 1989 series received approximately 9.7 yr of precipitation in the first 73 days of testing. No contraction of material or pulling away from the column walls was noticed during the dry periods in either test series.

Leachate leaving the columns showed some variation in quantities because of porosity and retentivity differences in the rock material. Loaded leachate solutions draining from the bottom of the columns were collected weekly, measured for pH value, and submitted for chemical analysis.

Reactivity of Midnite Mine Rock Samples

Results of reactivity testing are presented here for three different categories of rock samples: those from acidic ore piles; those from alkaline ore piles; and those from waste rock piles. Those rock types containing significant quantities of calcite yielded leachates with alkaline pH; those rock types with little calcite present produced leachates with acidic pH. Some piles showed both alkaline and acidic behavior depending on sample site. Leachates produced by duplicate columns were identical with respect to uranium concentration and pH values, indicating that reproducibility of the results is very good. Table 3 shows the range of leachate pH values obtained from each of the rock piles.

Acid Ore Piles

Sulfidic ore piles are characterized by acidic leachate pH values; piles 1, 3, 4, C, and G-1 are placed in this category. High pH values shown in table 3 for Ore Pile 3 came from the 1989 sample collected from 4.5 m deep in the pile, indicating a wide variation in mineral content within the pile. High pH values shown for Ore Pile C came from the 1988 sample, which came from the north side of the pile while the 1989 depth samples came from the east side and again show a variation in mineral contents. High pH values for Ore Pile G-1 came from one of the

Table 3. Range of leachate pH values obtained during reactivity testing of each rock pile

Rock pile	pH range
ACIDIC ORE PILES	
Ore pile 1	2.5 - 5.3
Ore pile 3	2.1 - 8.1
Ore pile 4	2.3 - 5.2
Ore pile C	2.0 - 8.4
Ore pile G-1	3.1 - 8.0
ALKALINE ORE PILES	
Ore pile A	7.6 - 8.5
Ore pile E	8.1 - 9.2
WASTE ROCK PILES	
Pit 2	2.0 - 3.9
Hillside Dump	2.6 - 9.1

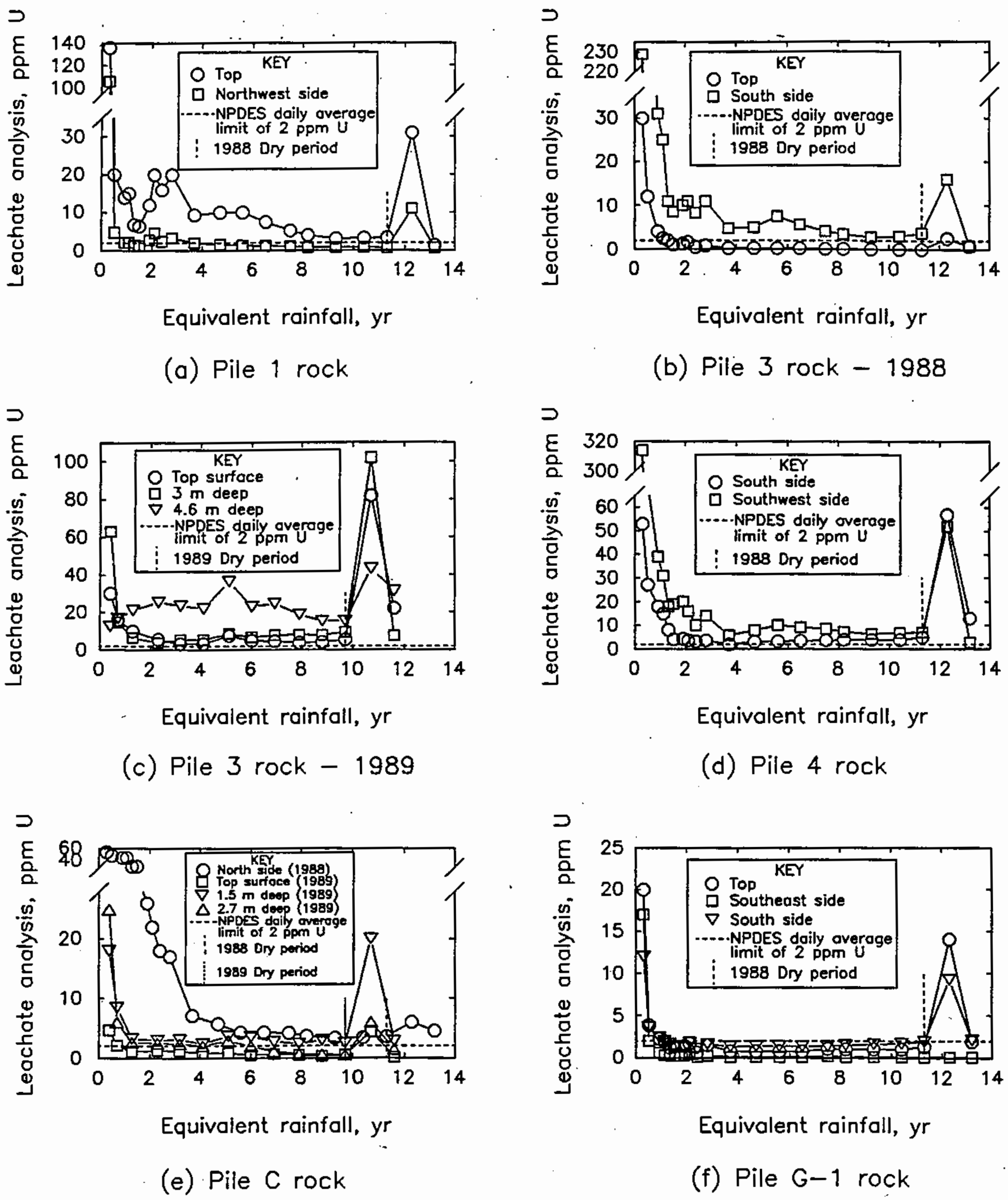

Figure 2. Acidic ore pile leachate concentration curves

three 1988 samples from that pile, whereas the other two samples exhibited acidic pH values.

Every rock sample from these five piles yielded initial leachates with uranium concentrations exceeding both the NPDES daily average limit of 2 ppm and the daily maximum limit of 4 ppm, as shown in figure 2 (a) through (f) (concentration curves for Ore Pile 3 are shown separately for 1988 (b) and 1989 (c) for ease of interpretation). Data in these figures are shown as years of equivalent rainfall applied to the columns plotted against uranium concentration of effluent from the bottom of the columns. Data presented in these plots clearly show that storm runoff from sulfidic rock piles following an extended dry period will require treatment before discharge.

This was confirmed by leachate uranium concentrations immediately following the dry period, which, as shown by the last two concentration data points in each of the plots, increased sharply up to 25 times the daily maximum discharge limit of 4 ppm U. In each case, there was an increase in the rate of uranium leaching immediately following the dry period, indicating oxidation of uranium minerals during the dry cycle; the rate then slowed to approximately the same uranium release rate as before the dry period.

Results from the 1989 depth sampling of Ore Piles 3 and C show that uranium contents and reactivities appear to be higher inside the piles, as shown in figure 2 (c) and (e), respectively. Even though the 4.5-m sample from Ore Pile 3 was quite alkaline, uranium content was over 1,000 ppm U and test leachates contained high levels of uranium.

Figure 2 (a) through (e) also show that rock from Ore Piles 1, 3, 4, and C will release uranium in excess of the NPDES daily average (2 ppm) during periods of extended rainfall. Ore Pile G-1, figure 2 (f), did not show this constant high level of reactivity during extended periods of rainfall, indicating that oxidation and release of uranium are slower in this pile.

Overall, if exposed to air, sulfidic rocks will oxidize uranium-bearing minerals and will then release this uranium contamination to runoff or ground water during a rain event. All of the sulfidic rock piles on the Midnite Mine site have this characteristic and must be isolated to prevent water contamination.

Alkaline Ore Piles

Alkaline ore piles are characterized by consistent high leachate pH values. Ore Pile E is acknowledged to be alkaline in nature, and Ore Pile A was placed in this category based on the single 1988 grab sample. Both of these piles show initial uranium leachate concentrations well above the daily maximum permit limit of 4 ppm U; but as the test proceeded, concentrations decreased to, and stayed below, the daily average limit of 2 ppm U, as shown in figure 3 (a) and (b). A dry period of 48 days in these tests did show some increase in uranium leachability in these piles, indicating that intermittent precipitation, especially if the intervals between storms are long, may produce runoff with uranium concentrations exceeding the discharge permit limits.

Approximately 4 yr of equivalent rainfall were initially required to flush uranium from the rock samples and to decrease leachate concentrations below the daily average discharge limit.

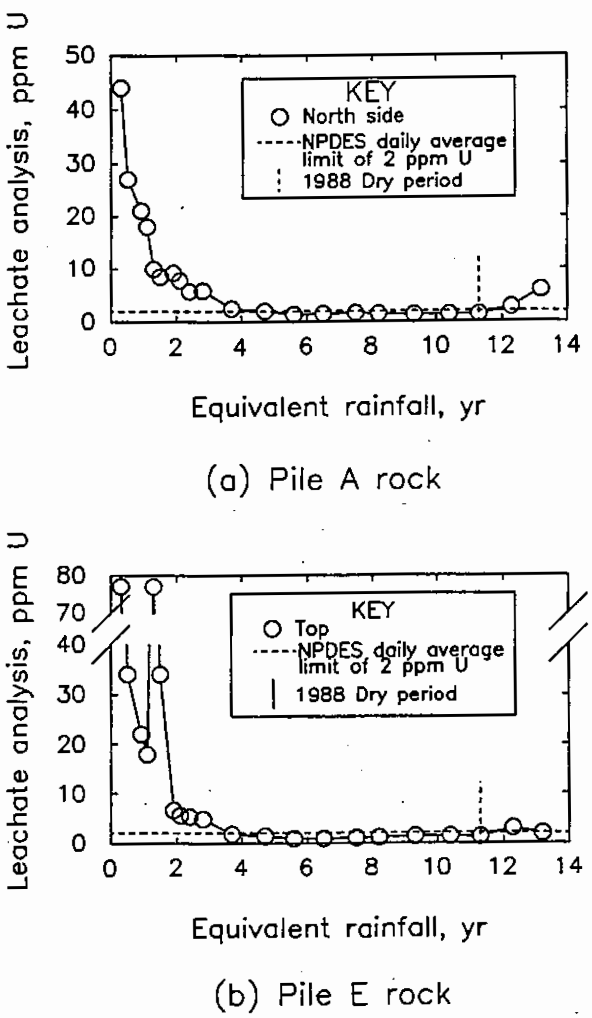

Figure 3. Alkaline ore pile leachate concentration curves

Limited leachate assays of the other metallic elements of concern were made in the alkaline rock tests. After 3 yr of equivalent rainfall, copper in the leachate from Ore Pile E rock assayed 0.3 ppm; and for the two weeks after the dry period, zinc in the leachate assayed 1.6 ppm. Both of these values are well above the daily maximum limits for these elements, showing that the alkaline rock is reactive with respect to these elements. Alkaline rocks, which increased the pH of the rainwater leachant, were not affected by the dry cycle nearly as much as were acidic rocks; but they will slowly and continuously release contaminant metals and should be isolated to prevent water contamination.

Waste Rock Piles

Waste rock piles sampled and tested for reactivity during the 1988 and 1989 programs included the Hillside Dump and Pit 2, which was one of the early open pits and which was later backfilled with waste rock from other pits.

Hillside Dump. Three samples were collected from the top of the Hillside Dump: one from the west end, one from the center, and one from the east end. Three other samples were collected from lift faces along the dump corresponding to soil pH values of 3, 6, and 7.

Rock samples from the top of Hillside Dump all exhibited alkaline characteristics during the column tests with leachate pH values near 8.5. Figure 4 (a) presents leachate uranium concentration data from these samples. The west end showed initial concentrations near 5 ppm U, which exceeds the daily maximum uranium limit. This sample also exceeded the daily average limit of 2 ppm during most of the test period, indicating that it is reactive and should be isolated from water contact. Following the dry period, leachate analyses increased to a level higher than that at the beginning of the test, indicating that oxidation during dry periods will increase uranium leaching during subsequent rainstorms. The other two top samples were not reactive with

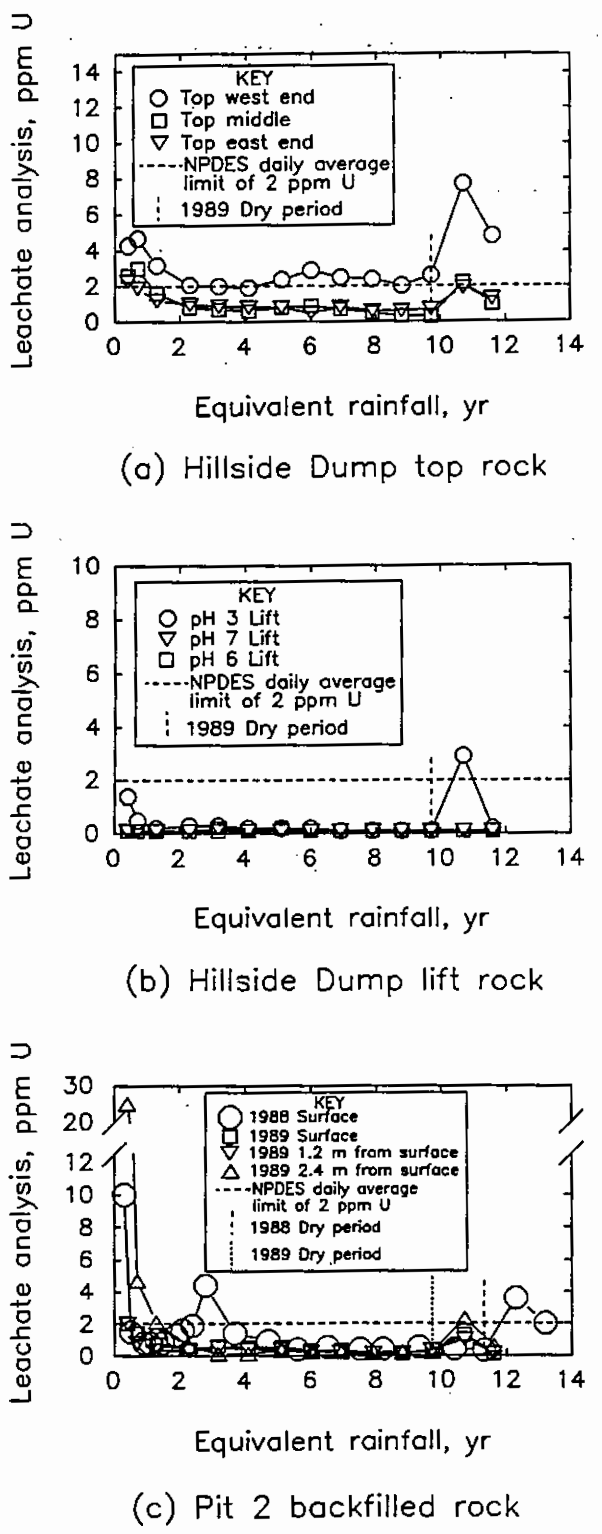

Figure 4. Waste rock pile leachate concentration curves

respect to uranium, and the high pH prevented leaching of other metals except calcium and magnesium. Although the top of Hillside Dump in an alkaline area, leach tests indicated a definite potential for uranium contamination in runoff water.

Lifts of the Hillside Dump were sampled in 1989 to get material with soil pH values covering the measured range of 3 to 7. Figure 4 (b) shows uranium results of testing these lift materials. Initial leachate analyses ranged up to 2.9 ppm U; but the consistent level before the dry period began was between 0.1 and 0.2 ppm for all samples. Oxidation during the dry period did increase the uranium reactivity of the pH 3 lift rocks; but, in general, materials from the lifts of Hillside Dump are not reactive with respect to uranium. Reactivity of other metals followed the same pattern as did the uranium with elevated concentrations of manganese, copper, and zinc in initial leachates and again following the dry period. Concentrations of these metals exceeded the NPDES limits for daily maximums after dry periods, as shown in table 4, which presents initial leachate concentrations for all Hillside Dump and Pit 2 rock samples. The Bureau considered the pH 3 material to be reactive with respect to non-uranium components of the NPDES permit.

The lifts with soil pH values of 6 and 7 yielded no reactivity. The only metals to leach from these two waste rock samples were calcium and magnesium. The Bureau considered these lifts to be nonreactive materials.

Results obtained with Hillside Dump material illustrate the wide range of reactivity levels present in the Midnite Mine piles. The presence of reactive rock on top of the dump and in the pH 3 lift may require that all of the dump material be treated as reactive. A more detailed examination of the dump will require a complex drilling and sampling scheme. The Bureau recommended that additional testing of the Hillside Dump be done to determine average reactivity.

Pit 2. Pit 2 waste rock produced the most acidic leachates of any of the Midnite Mine samples, as shown in table 3. This is reflected in the leach characteristics of manganese, copper, and zinc, which show leachate concentrations in excess of NPDES limits, both daily maximums and daily averages. Initial leachate concentrations of these metals are shown in table 4. Pit 2 waste rock is reactive with respect to these NPDES components and should be isolated to prevent water contamination with acid and metals.

Initial uranium leachate concentrations were also in excess of NPDES maximum daily limits in the test of waste rock from 2.4 m deep in the pit; however, after the first 2 weeks of testing, uranium analyses for all leachates were consistently between 0.1 and 0.7 ppm U. Following the 48-day dry period, analyses increased to between 1 and 2.5 ppm U in the first leachate, but the analyses quickly fell back to the same levels as before the dry period. These data are plotted in figure 4 (c). Runoff water from this material may exceed NPDES uranium limits. This Pit 2 material needs further evaluation.

Current Work

The small number of samples collected in 1988 and 1989 was not conducive to statistical validity of reactivity data. To provide reliable, statistically valid data on uranium content and reactivity, the Bureau has initiated a more complex sampling and leach testing program. Waste rock piles on the Midnite Mine site are composed of rock from different areas of the mine and are not homogeneous, which presents a difficult problem in determining average or typical reactivity. A drilling program was carried out in May and June of 1992 to collect samples from both the surface and the interior of Hillside Dump, Pit 2

Table 4. Initial leachate concentrations of manganese, copper, and zinc for waste rock samples

Waste rock sample	Initial leachate concentration, ppm		
	Mn	Cu	Zn
Hillside Dump (top-west end) . .	0.2	<0.5	<0.3
Hillside Dump (top-middle) . . .	<0.2	<0.5	<0.3
Hillside Dump (top-east end) . .	<0.2	<0.5	<0.3
Hillside Dump (pH 3 lift)	25	2.7	4.2
Hillside Dump (pH 6 lift)	<0.2	<0.5	<0.3
Hillside Dump (pH 7 lift)	<0.2	<0.5	0.7
Pit 2 (surface)	61	10.2	9.2
Pit 2 (1.2 m from surface) . . .	125	9.8	11.9
Pit 2 (2.4 m from surface) . . .	1260	34.1	92.5

backfilled material, and another large waste rock pile known as South Spoils. This is the first phase of a more systematic sampling program to determine reactivity of on-site materials.

Drill chip samples collected from these three waste rock sites are being wet-screened through 100 mesh to remove fines and to wash out residual drilling fluids. Preliminary column tests with plus 100 mesh material showed that plugging is not a problem with this size fraction; however, testing is still in progress to insure that oxygen is available to all parts of the column with the smaller size particles. Also the drill chips have not been further crushed; and the column diameter has been increased from 3.8 cm to 6.4 cm to accommodate the larger particles, which range up to 2.5 cm in size. Determination of reactivity in laboratory tests using relatively small-sized particles with corresponding large surface areas yields a "worst case" scenario. Testing of the 1992 samples will also include more dry periods interspersed among the leach periods to provide a better indication of reactivity changes immediately after dry periods.

The Bureau is also considering tests to evaluate the contribution of minus 100 mesh material to reactivity. Analyses completed to date indicate that this fine fraction constitutes between 6 and 53 wt pct of the drill chip interval samples and averages 21 wt pct of the interval samples. Chemical analyses of the fractions indicate that up to 50 pct of the NPDES elements of concern may be contained in the fine fraction and may thus have a significant effect on the reactivity. Tests under consideration are agitation leaching and/or long-term shaker-table leaching.

Summary

Results from preliminary testing of surface grab samples from various rock piles at the Midnite Mine indicate that (1) low-grade ore is reactive and will require isolation from ground and surface water and (2) waste material needs further evaluation. A more systematic sampling program has been initiated to develop reactivity profiles of stockpiled waste materials on the site.

References

Bradham, William S. and Frank T. Carruccio. 1991. A Comparative Study of Tailings Analysis Using Acid/Base Accounting, Cells, Columns, and Soxhlets. Proceedings of the Second International Conference on the Abatement of Acidic Drainage, Vol 1, pp. 157-173. (Montreal, Canada, September 16-18, 1991)

Coastech Research, Inc. 1990. Acid Rock Drainage Prediction Manual. Prepared for CANMET - MSL Division, Department of Energy, Mines, and Resources, Canada, November, 1990.

Sobek, Andrew A., William A. Schuller, John R. Freeman, and Richard M. Smith. 1978. Field and Laboratory Methods Applicable to Overburdens and Minesoils. U.S. Environmental Protection Agency Publication EPA-600/2-78-054, pp. 45-47, Cincinnati, OH.

U.S. Environmental Protection Agency. 1986. National Pollutant Discharge Elimination System (NPDES) Permit No. WA-002572-1. Issued September 30, 1986.

U.S. Geological Survey. 1989. Quality of Water in an Inactive Uranium Mine and its Effects on the Quality of Water in Blue Creek, Stevens County, Washington, 1984-85. Water Resources Investigations Report 89-4110: 20.

3A. RECLAMATION PLANNING