The Feasibility of Lining Tailings Ponds

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Introduction

This report addresses the technical feasibility of lining waste rock piles and tailing ponds. Currently, most tailings ponds and waste rock piles are not lined. The Environmental Protection Agency (EPA) studied tailings ponds and waste rock piles in a 1985 Report to Congress on Wastes from the Extraction and Beneficiation of Ores and Minerals (1985 RTC). EPA found that although both synthetic and natural liners can be used cost-effectively in relatively small disposal areas, they have not been used in the very large waste facilities that are typical of mining industry waste sites. Further, EPA believed that it would be difficult to evaluate the performance of liners at large-area, large-volume sites and that if a liner underlying such a large waste area failed, it would be impossible to repair. EPA made a 1986 Regulatory Determination based on the Report to Congress reiterating that large mine waste units were not typically lined, that lining such units may be infeasible, and liners if used could fail and not have the ability to be repaired.

However, since 1986, EPA has continued to collect information on the design and application of liners at mine sites. In contrast to the findings of the 1985 Report to Congress and 1986 Regulatory Determination, EPA presents information indicating that it is feasible to line certain types of mining waste management units, including mining tailings ponds and waste rock piles, where appropriate to protect the environment. Further, EPA has information indicating that some facilities currently use liners under certain circumstances.

Western Governors Association 1991 Study

In 1991 the South Carolina Department of Health conducted a study for the Western Governors Association entitled, Abstracts of Selected Precious Metal Mine Permits (December, 1991). The purpose of this report was to evaluate the design and operating characteristics found in permits of operating gold mines in Alaska, Colorado, Montana, Nevada, South Carolina, South Dakota, and Utah. This report reviewed permit requirements on 46 mines. This report is important since it clearly identified a number of hard rock (gold) mines routinely using liners in their tailings ponds.

- The Gold Hill Ventures mine had a 30 mil polyethylene liner underlain by compacted granite. Two monitoring wells were placed down gradient of the unit to monitor leakage.

- The San Luis Mine operated by Battle Mountain had a 192 acres tailings pond. The pond had a 12 inch compacted foundation and liner bedding in 2 inch lifts. The liner was a 40 mil VLPDE. Drainage was picked up by a coarse gravel material over the composite liner along with perforated pipe.

- The Nerco Victor project had a 13 acre tailings pond with a subbase of coarse tailings covered by a 20 mil PVC liner.

- The Marigold mine was designed with a compacted clay liner in 6 inch lifts having a 2 x 10 -7 cm/sec permeability covered by a 40 mil VLDPE liner.

- The Newmont Rain mine originally did not have a liner system but the original design was altered and subsequent lifts included a liner design using 80 mil HDPE liners.

- The Kennecott Ridgeway Mine tailings design uses a one foot base of compacted soil with an underdrawn covered by a 60 mil HDPE primary liner. In areas of higher stress 80 and 100 mil liners were installed. A drainage mat on top of the liners was placed to draw off excess flow away from the liners.

EPA 1991 and 1992 Mine Site Visits

EPA initiated a series of visits to operating mines in 1991 and 1992 to better understand waste management practices at operating mines. During these visits EPA collected information on the design and operation of tailings ponds to determine if such units were being lined in some fashion, and if not the reasons why liners were not being installed.

EPA visited the following mines: Asarco Troy (copper) in Montana, Newmont Rain in Nevada (gold), Cyprus Thompson Creek (molybdenum) in Idaho, LTV Steel (iron) in Minnesota, Phelps Dodge Morenci (copper) in Arizona, Doe Run Fletcher (lead) in Missouri, Brewer (gold) in South Carolina, IMC Four Corners (phosphate) in Florida, Pennzoil Culberson (sulfur) in Texas, Nerco Cripple Creek (gold) in Colorado, Copper Range White Pine (copper) in Michigan, Magma San Manuel (copper) in Arizona, Colosseum (gold) in California, and several gold placer mines in Alaska, including the Valdez Creek Mine.

EPA prepared a case study report on each facility. The mine operators were provided an opportunity to comment on their respective site visit report and their comments have been included in each respective report. These site visit reports have in turn been incorporated into technical resource documents which provide a detailed description of each mining sector. EPA has released all of these documents to the public in 1994 and they are available on the Internet since March,1995.

EPA found that most tailings ponds were 200-400 acres in size, and in some cases multiple tailings ponds were developed on a single mine site. The size of tailings ponds in the copper sector appeared to be significantly larger than average.

The site visits also noted that most tailings ponds used some form of barrier on the bottom and sides of tailings ponds to retard flow of water through the bottom. Most tailings ponds studied either used compacted earth or used tailings to “slime” the bottoms of the unit. The Agency confirmed the findings of the WGA report during the visit to the Newmont Rain mine. As noted earlier, the Rain tailings pond utilizes a variety of liner designs.(see the Newmont Rain mine site visit report).

The WGA report and Agency site visits conducted in 1991 and 1992 confirm that tailings ponds were being lined and that there did not appear to be significant engineering constraints to their installation.

During the 1991 site visits, state officials indicated to EPA that the Stillwater Mine in Montana had a long history of using liners in its tailings pond. Agency staff visited the Stillwater mine in 1992 as participants in the Colorado School of Mines Energy and Minerals Field Institute program.

1992 Visit to the Stillwater Mine

The Stillwater Mine is an underground platinum palladium mine located in an alpine environment in Montana. Tailings pond design began in the early 1980's and the first tailings dam was constructed in 1986. Whole tailings are separated by cycloning into the coarse and fine fractions; coarse fractions are deposited underground and fine fractions are placed in the lined tailings impoundment.

The engineering plans for the tailings impoundment indicate that whole tailings on occasion may be deposited in the tailings impoundment. A total tailings production rate of 500 dry tons per day during the first 4 years (approximately half that to be disposed in the impoundment as fine tailings) were estimated for tailings design. From year 5 forward a total tailings production rate of 1000 dry tons/day (approximately half that to be disposed in the impoundment as fine tailings) were estimated for tailings design. Tailings production was estimated to occur 330 days per year, 24 hours a day. The tailings were assumed to have a solids content of 30 percent and the fine fraction was assumed to have a solids content of 18 percent.

The tailings impoundment design, a side hill modification, called for the embankment to be raised in four stages throughout the life of the mine. This layout and the final dam crest elevation were based on the preliminary studies and a mine life of 20 years. The maximum height of the dam will be 130 feet and the crest width was designed to be 20 feet to accommodate vehicle traffic and a tailings slurry pipeline. The upstream slopes of the dam were designed at 1.6:1 and the downstream slopes at 2:1 as determined through static and dynamic stability analyses.

Impoundment excavation occurred in stages one and two to provide construction materials for the embankment and to increase the storage capacity of the impoundment. Each new stage of the embankment will be added in the downstream direction.

The embankment stage and estimated stage life statistics are listed below as based on a 1987 startup date.

Stage Number	Dam Crest Elevation	Approximate Year Dam Stage Construction Completed	Approximate Year Stage Filled
1	5045	1986	1992
2	5077	1991	2002
3	5096	2001	2007
4	5102	2006	2009

The impoundment was designed to store the design flood volume. The design freeboard (3 feet while containing the design flood volume) was determined from the flood storage volume and operational considerations.

The impoundment is monitored for settlement using survey monuments located along the dam crest. Piezometers were to be installed in the dam foundation to monitor for seepage.

The design called for the installation of a synthetic liner to minimize the migration of effluent from the impoundment to ground water. The installation of the 100 mil HDPE liner was planned in stages to coincide with the embankment raises. This plan not only reduces cost but also prevents potential damage to portions of the liner that would have been exposed for many years. The liner was selected based on economy, chemical resistance, resistance to weather, constructability and strength and durability. Installation procedures for the liner required the removal of all objects (rocks, clods, debris, sharp objects, etc) that could potentially damage the liner.

At the time of the visit, July, 1992, Stillwater Mine representatives indicated that liner installation had not encountered any unusual problems, and that the liner system appeared to be operating properly.

Other Large Units with Engineered liners

As noted earlier, EPA conducted a number of site visits in 1991-92. In 1992, EPA visited the Magma Copper-San Manuel copper mine in Arizona. During this visit, the Agency was informed by Magma of their success in lining a very large copper dump leach unit. Phase I of the heap leach, 83 acres, was completed in 1985; Phase II, 30 acres, in 1988; Phase III, 43 acres, in 1989; Phase IV, 35 acres, in 1990; Phase V, 24 acres, in 1991; and Phase VI, 11.5 acres in 1992. (Magma, 1991-APP)

The Magma heap leach pile has an design height of approximately 400 feet in 1992. (Helmer, 1992). In construction of the initial leach pad, soils beneath the leach pad were compacted and a 7.5 ounces per square yard layer of geotextile material liner was installed prior to laying the leach pad. According to Magma representatives, the leach pad is underlain by Gila Conglomerate with a permeability of 3.3×10^{-7} cm/sec. Initially, three thicknesses of HDPE liners were used to make up the original 113-acre leach pad: a 60 mil high density polyethylene (HDPE) lined 71 acres; a 100 mil HDPE lined 17 acres; and a 40 mil HDPE lined the other 25 acres. Which areas of the leach pad were covered with which liner type was not described. Apparently, 60 mil liners were used over ridges of the heap, while 100 mil liners were used to line collection ditches. Eighteen inches of gravel were placed on top of the liner to prevent tearing and a collection system of perforated pipes was installed to prevent pooling. (State of Arizona, 1989) According to San Manuel's 1989 Aquifer Protection Permit, construction and expansion of the heap leach was organized in six phases.

Leach pad extensions were prepared in a similar manner to the Phase I pad, however only 6 ounces per square yard of geotextile material was used to overlay the prepared sub-grade, and 60 mil and 80 mil HDPE liners were installed. The 80 mil liners were used to line solution collection channels. (State of Arizona, 1989) Collection channels along the southern edge of the heap are 16 feet wide by 2.7 feet deep.

The engineering success of lining such a large unit (while not a tailings pond) further proves that the mining industry is able to design, construct, and operate very large lined units.

1994 Tailings Pond Study

After conducting site visits, and determining that liners were in fact being installed in some mines, the Agency decided to conduct a comprehensive review of the literature on he design and operations of tailings ponds to determine if there were factors other than cost limiting the application of liners in tailings ponds. In 1994 EPA released a final report entitled, Design and Evaluation of Tailings Dams, (EPA 530-R-94-038) which assessed the literature on the design of tailings ponds. The Agency's 1994 study did not find any engineering reasons why several different types of liners could not be installed in tailings ponds. As a result of the literature search the

Agency also identified other mine waste units being lined (phosphogysum), a waste not unsimilar to other mine tailings.

This report also noted that seepage from tailings ponds was encouraged to lower the phreatic surface and increase stability. Vick (1990)and Ritcey (1989) discuss in their respective tailings studies how to accurately calculate seepage rates from tailings ponds to achieve stability. Theses reports conclude that unlined tailings ponds are designed to allow for flow through the unit into the ground.

<u>1996 Proposed New Tailings Pond at the Stillwater Mine</u>

In September, 1996, the Forest Service and the Montana Department of Environmental Quality (MT DEQ) announced in the Federal Register that they were preparing an environmental impact statement(EIS) on the environmental effects due to construction and operation of a new tailing impoundment facility 7 miles from the current Stillwater Mine. The following information was summarized from data contained in the FR notice.

The Stillwater Mining Company has been in operation since 1986. SMC is currently in the process of expanding ore production from 1000 tons per day to 2000 tons per day. At the present rate of production, SMC's permitted tailings impoundment will reach its ultimate capacity by the year 2003. Given the projected life of the current tailing facility, SMC is proceeding with the permitting of an additional tailings pond.

The proposed tailings pond would be located at the Hertzler Ranch. The Hertzler Ranch is situated approximately seven miles northeast of the mine site. Construction of the Hertzler Impoundment would utilize local borrow materials, therefore this amendment proposes to store waste rock on permitted waste rock sites located on the east side of the Stillwater River. This area is currently occupied by a part of the mine waste water disposal system, known as the Land Application and Disposal system (LAD). Once construction begins on the east side waste rock storage area, the LAD system would be moved. To insure that production levels can continue uninterrupted and that operational flexibility is maintained, SMC will continue to utilize the existing tailing impoundment. As currently proposed, the two impoundments would be operated in concert. This action will result in approximately 271 acres of additional disturbance and will increase the total permitted acreage by 1,112.

Construction of the proposed tailing embankments will incorporate staged expansion using local borrow materials, identified during the 1981 site investigation program. The embankment would be constructed using the centerline method to a height of approximately 155 feet(elevation 5,036 feet) at the deepest section and would accommodate storage of approximately 13 million cubic yards (12.3 million tons) of tailings. This facility will cover approximately 146 acres after construction.

SMC is proposing to utilize a high density polyethylene (HDPE)liner within the impoundment. A system of spine underdrains would be incorporated to promote consolidation of the tailings mass during operations. Seepage collected from the underdrains and from the embankment filter drains would drain to recycle ponds situated around the perimeter of the facility. From the recycle ponds, this tailings water would be pumped back to the tailings impoundment for reuse in the milling and concentrating process.

<u>1997 Study of Phosphogypsum Stacks</u>

The Agency conducted a study to compare the design and operating standards for uranium mill tailings with those established by Florida for phosphogypsum stacks. (See Feasibility Analysis : A Comparison of Phosphogypsum and Uranium Mill Tailing Waste Unit Design, USEPA 1997) . The design standards established under the Uranium Mill Tailings Reclamation Act (40 CFR 192) were designed to protect groundwater from disposal units holding uranium mill tailings. These tailings are similar in size and density to tailings generated in hardrock mining. These standards have also been in place since 1983. The Agency felt it would be beneficial to compare feasible tailings pond design criteria used for uranium tailings and compare those with phosphogypsum regulations, since both wastes are radioactive and as noted earlier are generally similar in size and density. During this study the Agency determined that four phosphogypsum stacks (New Wales, Ft. Meade, plant City, and Nichols) were either built or in the design phase which represented new approaches to managing this type of wastes.

The 1993 Florida Phosphogypsum Management regulations are less stringent than the uranium mill tailings standards defined in 40 CFR 192 Subpart D in several important respects. First, the uranium tailings standards require a double composite liner with two geomembranes and an underlying layer of 3 feet of compacted soil with minimum hydraulic conductivity of $1x10^{-7}$ cm/sec. The gypsum standards require only one geomembrane and 2 feet of compacted gypsum with minimum hydraulic conductivity of $1x10^{-4}$ cm/sec (or an underlying 18-inch layer of compacted soil with maximum hydraulic conductivity of $1x10^{-7}$ cm/sec, which has not been used in any of the four cases analyzed in Section 4). Second, the uranium tailings standards require a leachate collection system that is also used as detection system. If the measured volume of liquids recovered exceeds a pre-determined action leakage rate, a response action plan is set in motion to mitigate or stop any leaks. In the gypsum case, leakage through the liner is expected and it is actually calculated in the technical reports presented in the permitting process.

- All three gypsum stacks constructed or proposed since the enactment of the 1993 Florida Phosphogypsum Management regulations have followed or exceeded the Florida standards but none of the designs approach the protectiveness of the uranium mill tailings standards.

- The Plant City gypsum stack proposal goes beyond the Florida standards due to the environmental sensitivity of the area (i.e., proximity of a potential future wellhead area) and, quite likely, because of increased public concern in Florida after recent environmental incidents in the phosphoric acid industry.

- A trend that is clearly noticeable in the technical reports presented to support the Florida permit applications is an increasing level of detail and analysis. For example, a new topic that is receiving more attention (both in field work efforts and proposed preventive measures) is sinkhole potential.

- The approach at the Nichols plant of a modified gypsum stack is interesting, as it allows usage of an old stack for the remaining years of its useful life, fulfilling at the same time the 1993 Florida regulation's closure requirements.

This report shows that phosphogysum stacks can be lined in units with average sizes exceeding 150 acres. Liner design usually involves the use of a 24 inch layer of compacted gypsum followed by a 60 mil geomembrane and the use of concentric underdrains. All of the four lined stacks will have extensive groundwater monitoring systems.

<u>1997 Study on Gold Tailings Ponds</u>

The Agency conducted a study to evaluate current State of Nevada gold cyanide mill tailings facility design, operation, and closure regulations, and compare them to the uranium mill tailings design and operating regulations promulgated at 40 Code of Federal Regulations (CFR) 192. (See Nevada Gold Cyanide Mill Tailings Regulation, US EPA, February, 1997). This report also evaluated the tailings pond designs used at three gold cyanide mill facilities in the State of Nevada. Nevada was selected for the comparison because it is the nation's largest producer of gold, has the largest number of gold cyanide mill facilities, and has promulgated the most advanced cyanide mill tailings facility regulatory framework.

The Agency has made the following conclusions regarding the two regulatory frameworks and the application of the Nevada regulations at three facilities. The minimum design criteria for the State of Nevada and 40 CFR 264 are substantially different. The State of Nevada minimum design criteria for tailings impoundments include a 12 inch thick soil liner with a coefficient of permeability of 10^{-6} cm/sec, or equivalent. The design criteria for tailings impoundments under 40 CFR 264 requires three layers of solution containment - two of flexible geomembrane and a bottom liner of 3 feet of compacted soil with a coefficient of permeability no greater than 10^{-7} cm/sec, with geotextile leak detection collection system between the liners. Nevada regulations require review of dam design, construction and maintenance requirements prior to issuing a dam permit. Neither 40 CFR 192 nor 260 specify requirements for the dam associated with a tailings impoundment. Nevada State regulations are written and enforced to prevent degradation to the waters of the state, where the 40 CFR 260 regulations are written to prevent any release to the groundwater. Because of this difference the Nevada regulations require identification of all drinking water sources, groundwater and surface water sources and quality. Nevada closure requirements are focus on preventing degradation of the waters of the state, and converting the land to a post-mining use. Also due to the low precipitation and high evaporation rates, typically state wide, final covers are designed to hold precipitation for subsequent evaporation. 40 CFR 264 requires removal of the waste from the impoundment, or dewatering, and stabilization of the wastes prior to installing a cover which will prevent precipitation from moving through the impoundment. Nevada regulations for post closure monitoring are established on a facility basis, but is no longer than 30 years. 40 CFR 264 requires monitoring of no less than 30 years.

Review of the liner designs at the Newmont Rain, Barrick Bullfrog, and Echo bay McCoy mines indicate that all were successfully constructed using either 12 inches of amended soil liners or synthetic liners in conjunction with compacted clay liners. It is important to note that while there are differences in regulatory approach between UMTRCA and Nevada, it is apparent that tailings ponds in Nevada are being lined and that there does not appear to be technological barriers to such installation.

Conclusions

This report summarizes a series of reports evaluating the design and installation of tailings ponds in hard rock mining. EPA believes that the size of land based units, the character of mining waste, and technical factors, do not necessarily preclude the use of liners or leachate collection systems. The Agency believes that liners assist in the prevention of uncontrolled discharges of hazardous constituents to the environment. This report finds that some mines, which represent typical mining sectors and practices, are currently lining their tailings ponds Further, there is a trend for states to require tailings ponds to be constructed with liners.