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Comprehensive Report: An Overview of Practices at Hardrock Mining and Mineral Processing Facilities and Related Releases of CERCLA Hazardous Substances

Final Report

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List of Acronyms

Acronym	Definition
ACGP	Alaska Construction General Permit
ADEC	Alaska Department of Environmental Conservation
ADEQ	Arizona Department of Environmental Quality
ADNR	Alaska Department of Natural Resources
ADWR	Arizona Department of Water Resources
AMD	Acid Mine Drainage
AMLRA	Arizona Mined Land Reclamation Act
APDES	Alaska Pollutant Discharge Elimination System
APMA	Application for Permits to Mine in Alaska
APP	Aquifer Protection Permit
ARAP	Aquatic Resource Alteration Permit
ATCM	Airborne Toxics Control Measure
ATSDR	Agency for Toxic Substances and Disease Registry
AWQS	Arizona Water Quality Standards
AZPDES	Arizona Pollutant Discharge Elimination System
BLM	Bureau of Land Management
BR	Biennial Report
BRS	Biennial Reporting System
CAA	Clean Air Act
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
CWA	Clean Water Act
DCHD	Douglas County Health Department
DEQ	Department of Environmental Quality
DMRs	Discharge monitoring reports

DOE	Department of Energy
DOI	U.S. Department of the Interior
DPNR	Department of Planning and Natural Resources
DRI	Developments of Regional Impact
EAW	Environmental Assessment Worksheet
ECHO	Enforcement and Compliance History Online
EIS	Environmental Impact Statement
ELGs	Effluent Limitation Guidelines
EPA	U.S. Environmental Protection Agency
ERNS	Emergency Response Notification System
ERP	Environmental Resource Permit
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FRS	Facility Registry System
HDPE	High Density Polyethylene
HRM/P	Hard Rock Mining and Processing
ICIS	Integrated Compliance Information System
IDEM	Indiana Department of Environmental Management
IDEQ	Idaho Department of Environmental Quality
IDL	Idaho Department of Lands
IDNR	Indiana Department of Natural Resources
ILO	International Labour Organization
ISL	In situ Leaching
IW	Industrial Wastewater
LDR	Land Disposal Restriction(s)
MACT	Maximum Achievable Control Technology
MANPHO	Mandatory Phosphate Program
MCLs	Maximum Contaminant Levels
MDEQ	Montana Department of Environmental Quality
MEPA	Minnesota Environmental Policy Act

MEPA	Montana Environmental Policy Act
MGWPCS	Montana Groundwater Pollution Control System
MIW	Mine-Influenced Water
MOU	Memorandum (or Memoranda) of Understanding
MPDES	Montana Pollutant Discharge Elimination System
MSHA	Mine Safety and Health Administration
MSSW	Management and Storage of Surface Waters Program
NAICS	North American Industry Classification System
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NSPS	New Source Performance Standards
NV DEP	Nevada Department of Environmental Protection
NV DNR	Nevada Department of Natural Resources
ODEQ	Oklahoma Department of Environmental Quality
OFW	Outstanding Florida Waters
OSDH	Oklahoma State Department of Health
OU	Operable Unit
PCB	Polychlorinated biphenyl
pH	Measure of acidity
PVC	Polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RDA	Residue Disposal Area
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RRC	Texas Railroad Commission
SCA	St. Croix Alumina

SDS	State Disposal System
SDWA	Safe Drinking Water Act
SMARA	Surface Mining and Reclamation Act
SMGB	Surface Mining and Geology Board
SO2	Sulfur Dioxide
SWPPP	Storm Water Pollution Prevention Plan
SX/EW	Solvent extraction and electrowinning
TAP	Toxic Air Pollutants
TCEQ	Texas Commission on Environmental Quality
TDEC	Tennessee Department of Environment & Conservation
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TRI	Toxics Release Inventory
U.S.	United States
UIC	Underground Injection Control
UMTRCA	Uranium Mill Tailings Radiation Control Act
UPDES	Utah Pollution Discharge Elimination System
USACE	U.S. Army Corps of Engineer
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UTS	Universal Treatment Standards
VMRP	Voluntary Mercury Reduction Program
WAD	Weak Acid Dissociable
WDRs	Water Discharge Requirements
WQS	Water Quality Standards
WRP	Wetland Resource Permit

Glossary

Acid mine drainage (AMD): a type of mine-influenced water and a major contaminant vector to surface and groundwater. When water is exposed to air and sulfide-bearing materials, forming solutions of net acidity and increasing the leaching and mobility of metals and trace elements. "Acid mine drainage" is sometimes referred to as "acid rock drainage" to clarify that acid in an environment may be generated by processes other than human mineral extraction and processing activities. Because this document deals with mining and milling practices, it will use acid mine drainage, henceforth AMD.

Adit: A horizontal passage leading into an underground mine for the purposes of access or drainage.

Beneficiation: preliminary processing such as grinding, gravity and magnetic concentration, flotation, and leaching that separate and concentrate minerals, such as in preparation for further refining, and does not generally result in a chemical change. Beneficiation involves the removal of uneconomic material from ore through physical and/or chemical methods to generate a product with a higher concentration of the valuable material and waste, called tailings. Exempt from regulation as a hazardous waste under RCRA Subtitle C.

CERCLA hazardous substances: elements, compounds, and hazardous wastes with statutory designation as hazardous substances under Section 102 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. For more information, see https://www.epa.gov/epcra/epcracerclacaa-ss112r-consolidated-list-lists-march-2015-version.

Contemporary mining: practices currently used and marked by technological sophistication and increased regulatory oversight. Technological advances allowed for more accurate characterization of unexploited ore bodies and more efficient processing, making lower grade economical to mine; an attendant increase in the number and size of mining operations that take advantage of economies of scale to increase their size while lowering their fixed costs (see below); an increasingly connected global economy which has led to a larger market for natural resources, multinational mining companies, and commodity cycles driven by the demands of developing countries' economies; and consideration for the potential deleterious social, economic, and environmental effects of mining operations, enforced by national and local regulatory regimes.

Dump leaching: involves the application of leach solution to uncrushed and otherwise unprocessed ore, directly from the mine. The dump leaching process can take up to two years to process a given ore pile and in some cases results in relatively low extraction rates. Because of its low cost, dump leaching is the most common leach method used for production of copper and is also used for nickel mining.

Economies of scale: the cost advantage from increased output. At larger mining operations, the per-unit fixed cost (e.g., of purchasing large machinery or investing in heap leaching pads) decreases because the costs are spread over a greater amount of product. Exploiting economies of scale makes lower grades of ore economical to mine.

Erosion: the moving of rock or other surface material by wind, rain, and other processes from one location to another. Mining can disturb large amounts of surface material and contribute to mine-influenced water, sedimentation, and other water quality problems.

Extraction: the process by which an operator removes valuable minerals from the ground, often requiring the removal of waste products (overburden and waste rock) at the same time. The extraction methods considered in this report are open pit mining, underground mining, and non-entry (in situ) mining.

Federal surface management regulations: the Bureau of Land Management (under 43 CFR Subpart 3809) and the United States Forest Service (under 36 CFR Part 228) permit and oversee mining activities on public federal lands. These agencies are charged with preventing "unnecessary and undue degradation" to public lands, and generally require the submission and approval of plans of operation for proposed activities, including an environmental assessment and reclamation plans. Other requirements include proper disposal, concurrent reclamation, and providing for post-mining monitoring, maintenance, and treatment.

Fugitive dust: particulate matter suspended in the air by wind action and human activities, such as extraction and milling. Because the dust may contain metals or chemical residues, human health and environmental problems may arise through direct inhalation, soil and plant deposition, or accumulation within a water body.

Heap leaching: the beneficiation process in which ore is placed on a leach pad on an impermeable barrier, leach solution is applied using sprinklers or misters, and the pregnant solution containing the liberated mineral of interest is collected. Due to cost efficiencies, heap leaching is typically used for treatment of low-grade oxidized ores.

Lixiviant: the solution used to extract minerals from ore in heap, dump leaching, and in situ leaching. The lixiviant captures the desired mineral when it comes in contact with the ore, then is transported to a separate processing stage where the mineral is pulled out of the lixiviant (for example, through ion exchange). Lixiviants can be reused.

Milling: the facility at which beneficiation, or processing, takes place. It usually includes equipment used for processing itself, and is connected to supplementary features that support processing: process ponds that house process liquid before use or reuse, tailings facilities that store processing waste, and transportation facilities to receive unprocessed ore and ship out processed concentrates.

Mine-influenced water (MIW): MIW encompasses any water whose chemical composition has been affected by mining or mineral processing. One type of MIW is AMD, but MIW also includes drainage that is neutral or alkaline. In addition to environmental concerns posed by acidity or alkalinity, MIW often contains elevated concentrations of mobilized contaminants, suspended solids, or sulfate or arsenate content.

Placer mining: Placer mining uses water to excavate, transport, and/or concentrate minerals from placer or alluvial deposits, where erosion and deposition have created deposits of minerals within sediments or rock fragments. This type of mining has been used predominantly for gold prospecting over the years, but has also been used for the recovery of platinum, silver, and heavy mineral sands containing tin, titanium, zircon, rare earths, or iron.

Point source: discharge from a discernible, confined and discrete conveyance. These discharges are regulated by NPDES permitting and other requirements under the Clean Water Act. Seepage to groundwater is not considered a point source, and is not regulated under the Clean Water Act. The classification of point and nonpoint discharges from mining operations has evolved over time.

Pregnant solution: a solution containing dissolved extractable mineral that was leached from the ore.

Primary processing: generally occurs after beneficiation and transforms concentrated mineral particles into a more useful chemical form, such as by heat (e.g., smelting) or chemical reactions.

Reagent: a substance added to a process to facilitate a desired chemical reaction, such as to liberate minerals from ore in leaching or flotation.

Overburden: non-mineralized material on top of ore deposits that must be removed in order to reach ore deposits. Typically stored on site and can be used for backfill and revegetation after mining operations are complete. The term may also be used to refer to waste rock, although overburden typically has a lower potential for environmental contamination. It is distinct from tailings, which remain after economically valuable components have been removed.

Reclamation and closure: refers to tasks conducted after mining operations have concluded to return the facility site to public use, and to ensure there are no post-operational releases. Tasks include monitoring the site, conducting water treatment if necessary, and covering and revegetating features that had created a surface disturbance, among others. Reclamation and closure is regulated under both federal surface management regulations (on federal land) and state regulations.

Seepage: the continuous release of fluid (e.g., from a tailings storage facility) into local soil, bedrock, or groundwater.

Tailings: the waste material created when valuable minerals or metals have been physically or chemically separated from ore. All beneficiation procedures generate tailings, in addition to mineral processing activities. Tailings usually take the form of a slurry (e.g., wet tailings), but may also undergo dewatering and disposal as paste or filtered tailings. Depending on the commodity and the beneficiation process, tailings may contain a variety of hazardous substances.

Tailings storage facility: general term that includes "ponds," "impoundments," and "dams." Many different types of facilities are used to contain and manage the tailings (waste ore) resulting from hardrock mining. Depending on the type of tailing (e.g., slurry, filtered, or paste), facilities may include liners, tailings ponds, and retention dams.

Trace elements: any element present in a substance in low concentrations, such as contaminants in mine-influenced water. Includes metals (e.g., gold, mercury), metalloids (e.g., arsenic), and nonmetals (e.g., sulfur).

Waste rock: material surrounding or within ore deposits that contains minerals in concentrations considered too low to be extracted at a profit. Its geochemistry may contribute to mine-influenced water. Typically stored on-site, sometimes co-disposed with tailings.

Introduction

Section 108(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended, establishes certain regulatory authorities concerning financial responsibility requirements. Specifically, the statutory language addresses the promulgation of regulations that require classes of facilities to establish and maintain evidence of financial responsibility consistent with the degree and duration of risk associated with the production, transportation, treatment, storage, or disposal of hazardous substances. On July 28, 2009, the U.S. Environmental Protection Agency (EPA) identified hardrock mining facilities (i.e., extraction, beneficiation, and processing of ores and nonmetallic minerals) as the initial class of facilities that will be subject to financial assurance requirements under CERCLA 108(b) (74 FR 37213). Consequently, EPA is developing a proposed rule to apply financial assurance requirements for facilities within this class.

Public comments received in response to the 2009 proposed notice questioned the need for these requirements in light of existing environmental regulatory programs at both the state and federal levels, and considering the risk of future releases of hazardous substances from current mining operations. As part of EPA's consideration of financial assurance regulations for facilities within identified sectors, EPA is evaluating the validity of these assertions. This document endeavors to address that topic by investigating the extent to which the implementation of federal and state environmental regulatory programs and current hardrock mining and mineral processing practices have affected the non-permitted releases of hazardous substances into the environment. It also discusses how the nature and frequency of releases and other impacts may have changed over time.

This document first summarizes the methodology of this review and resulting conclusions. Each of the sections that follow describes the status of extraction, processing and waste management methods in the United States and provides a technical description of how they are implemented. Next, the potential sources of hazardous releases are described, as well as the regulatory framework in place to manage mining and processing practices. Finally, evidence from specific non-operating sites and currently operating facilities is presented in order to analyze the past and current non-permitted releases and their causes. Appendices include additional information on methodology and applicable regulations.

Methodology

The methodological approach focuses on several major extraction (mining), mineral processing, and waste management practices. Hardrock mining is the extraction of rock and other materials from the earth that contain a target metallic or non-fuel non-metallic mineral. The extraction processes include in situ solution mining, extraction of mineral-bearing groundwater brines, and surface or underground excavation of solid earthen materials. Mineral processing includes practices following the extraction of mineral ore that involve the separation and/or concentration of metallic or non-fuel, non-metallic minerals from the ore, and to refine ores or mineral concentrates to extract a target material.

Initially, this research effort focused on characterizing practices within each commodity sector.[1] EPA concluded that a better approach was to focus specifically on mining, processing, and waste management practices that are commonly used within the U.S. hardrock mining industry, regardless of the commodity. Many processing practices, such as physical processing, flotation and leaching are applicable to many commodities. Several distinct waste management practices are also applicable to the majority of currently operating facilities. Furthermore, practices are more determinative of the hazards related to releases than the commodity, as specific process chemicals and methods are used in mining and mineral processing of multiple commodities. Although there are strong correlations between certain practices and commodities (e.g., Bayer processing for aluminum or ion exchange for uranium), those correlations are noted in the relevant practice papers.[2]

Each following section includes discussions of major extraction, mineral processing, or waste management practices. These practices include:

- Surface and Underground Mining
- Non-Entry (Solution) Mining
- Physical Processing, Gravity Processing, and Magnetic Processing
- Flotation
- Cyanidation
- Acid Leach, Solvent Extraction, and Electrowinning
- Pyrometallurgical Processes
- Bayer Process for Aluminum
- Mine-Influenced Water
- Waste Rock Piles
- Tailings Management

[1] EPA developed a list of hardrock commodities under consideration for this rulemaking. The list of 33 hardrock commodities excludes several commodities that are not expected to be mined or processed in the United States in the future based on USGS mineral profiles (e.g., arsenic, asbestos, columbium, gallium, mercury, and thorium). For more information, please see: U.S. Environmental Protection Agency, *Memorandum: Mining Classes Not Included in Identified Hardrock Mining Classes of Facilities* (Washington, DC: U.S. Government Publishing Office, 2009). Accessed at http://www.regulations.gov/contentStreamer?documentId=EPA-HQ-SFUND-2009-0265-0033&disposition=attachment&contentType=pdf.

[2] For example, gold and silver frequently co-occur in ore and can be extracted using cyanide leaching. For information regarding the common techniques for several commodities, see: U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995). Accessed 14 December 2015 at: https://www.epa.gov/sites/production/files/2015-05/documents/epa_metal_mining_sector_notebook.pdf

Each practice's subsection is structured similarly and discusses the following topics:

- Past and current use;
- Technical description;
- Potential sources and releases of CERCLA hazardous substances and management practices to address those potential sources and releases;
- Applicable state and federal regulations; and
- Documented releases at non-operating sites and currently operating facilities.[3]

For each practice, information was gathered through a literature review spanning technical references, academic sources, and government publications.[4] To the extent possible, historical methods were distinguished from contemporary techniques. The discussion of relevant regulatory frameworks for each practice drew upon prior EPA research of environmental regulations applicable to mining (see Appendix IV), supplemented by additional research to target each practice.

To develop a profile of past and contemporary practices and environmental releases of CERCLA hazardous substances associated with each practice, publicly available information was gathered for a sample of 29 non-operating hardrock mining and primary processing CERCLA sites, as

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[3] "Currently operating facilities" refers to facilities that have not formally entered closure as of July 2015, and includes all active, intermittent, or temporarily idled hardrock mining and mineral processing facilities. These facilities were identified using data from the Mine Safety and Health Administration, U.S. Geological Survey, and other public sources. EPA identified "non-operating" sites for this document by drawing upon mines and mineral processors that have undergone cleanup activities under CERCLA authority. In some cases, currently operating facilities may have portions that no longer have ongoing mining or processing activities, or portions designated as CERCLA cleanup sites. Throughout this document, EPA refers to "non-operating sites" as either those that were not identified as currently operating, or those where a portion of the mine or processing facility is no longer in use and has undergone CERCLA cleanup activities (e.g., legacy pits, ponds, or waste piles).

[4] Several references provided information used throughout this document. These include:

- U.S. Environmental Protection Agency, *Technical Resource Documents: Extraction and Beneficiation of Ores and Minerals* (Washington, DC: U.S. Government Publishing Office, 1994).
- U.S. Environmental Protection Agency, *Sector Notebook Project: Profile of the Nonferrous Metals Industry* (Washington, DC: U.S. Government Publishing Office, 1995). Accessed December 14, 2015, at: https://nepis.epa.gov/Exe/ZyPDF.cgi/50000FOZ.PDF?Dockey=50000FOZ.PDF
- U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995).
- National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002). Accessed August 2, 2015, at: http://www.nap.edu/catalog/10318/evolutionary-and-revolutionary-technologies-for-mining.
- J.J. Marcus, ed., *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining* (London: Imperial College Press, 1997).
- Peter Darling, ed., *SME Mining Engineering Handbook*, Third Edition (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volumes 1-2.

well as a sample of 70 currently operating facilities in the United States.[5,6,7] The sites and facilities examined represent stratified samples by primary commodity (see Appendices I and II). For some practices, additional non-operating sites and currently operating facilities are discussed to further illustrate the relevant issues. Information about non-operating sites was gathered largely from Record of Decision (ROD) and Remedial Investigation/Feasibility Study (RI/FS) documents. Information about currently operating sites came from various EPA databases, Emergency Response Notification System (ERNS) incident notifications, Mine Safety and Health Administration (MSHA) records, federal and state permit documents, and general research.

ERNS is used to store information on notifications of oil discharges and hazardous substances releases.[8] ERNS contains, in addition to other data, information about the material and the quantity released, where the release occurred, when the release occurred, and information about property damage, injuries, and deaths occurring due to the release. ERNS primarily contains initial accounts of releases reported to the National Response Center (NRC); exact incident details or follow-up actions may not be reported.

From the National Response Center (NRC) website, EPA aggregated reports for the period 1990-2014 and identified unique incidents involving CERCLA hazardous substances at hardrock mining facilities. Due to the nature of the reporting framework, these data do not include much information about continuous releases or information about releases after facility closure.

Review of individual site permits, environmental impact statements, and other documentation was outside of the scope of this report. Appendix III provides further discussion of the protocol used to gather information about non-operating sites and currently operating facilities. Where the protocol did not result in significant information, consultation with mining experts also informed the search for case studies.

This document does *not* endeavor to develop a formal risk assessment of the non-operating and currently operating sites and facilities. This effort also does not endeavor to evaluate past actions at the historical cleanup sites. Systematic and comprehensive information about facility

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[5] The sample of currently operating facilities relied on a list generated on November 18, 2014. Additional research into the facilities in the sample may have uncovered that some of them stopped operating or have temporarily suspended their activity. Where applicable, this document notes such instances. However, no effort was made to continuously review the operational status of the facilities.

[6] All references to “facilities” discuss currently operating facilities, while “sites” refer to non-operating sites. All references to “sites” and “facilities” cover both hardrock mining and mineral processing sectors.

[7] For a complete list of the sample non-operating sites and currently operating facilities, see Appendix III.A. and III.B

[8] The types of release reports that are available in ERNS fall into three major categories: substances designated as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended; oil and petroleum products, as defined by the Clean Water Act of 1972 (CWA), as amended by the Oil Pollution Act of 1990; and all other types of materials. Because CERCLA defines hazardous substances to include CWA hazardous substances and toxic pollutants, the Clean Air Act hazardous air pollutants, the Resource Conservation and Recovery Act (RCRA) hazardous wastes, and the Toxic Substances Control Act imminently hazardous chemical substances, releases of these substances are also subject to CERCLA reporting requirements.

characteristics, waste management, releases, and regulatory oversight was not available for either non-operating sites or currently operating facilities. Thus, this profile is based on information that may be incomplete or anecdotal. For example, ROD, RI/FS, and permit documents provide narrative information; the absence of discussion of certain processes, activities, or occurrences cannot be taken as evidence of the fact that they did not take place.

The analysis conducted represents a general assessment of the occurrence of releases, and is also subject to the following data limitations:

- **Data Availability:** A range of publicly available CERCLA documents contained information about releases from the sample of non-operating sites. Documentation about operations and releases at currently operating facilities was inherently more difficult to find, absent major enforcement actions.
- **Magnitude and Severity of Releases:** This review did not attempt to characterize the environmental or human health risks associated with specific releases. No comparison of magnitude and severity was drawn between releases at non-operating sites and currently operating facilities.
- **Legacy Contamination:** Many sites and facilities within the non-operating and currently operating samples have been active for a century or longer. When a post-1980 release occurred at these facilities, it was difficult to determine if the equipment or practice responsible for the release was newly constructed or part of the site's past operations.

Certain drafts of practices discussed in Sections 1 and 2 of this document have undergone limited peer review by U.S. Geological Survey (USGS) staff and an independent mining expert.

Conclusions

The research effort yielded several insights concerning the extent to which the implementation of federal and state environmental regulatory programs, along with current mineral extraction, beneficiation, and processing practices in the United States, have affected the releases of hazardous substances into the environment. Overall, the review of regulations, practices, and past and current releases showed that despite changes in regulations and practices, the release of CERCLA hazardous substances as a result of mining and mineral processing activities is an ongoing issue across varying industry management practices. Extraction practices generally do not involve the use of hazardous chemicals, with the exception of non-entry mining. Nonetheless, releases resulting from surface and underground disturbances do occur. The potential harm related to each respective processing practice depends upon the nature of the chemicals the process uses. Waste management, i.e., generation, transportation, treatment, storage, and disposal, are practices with overarching concerns.

Past Experience

EPA has determined that 102 non-operating CERCLA sites that have ceased mining and mineral processing activities, including sites on the National Priorities List (NPL) and sites at which removal actions occurred, experienced releases resulting from industrial activity in the hardrock mining and primary processing sectors. From these 102 sites, EPA selected a sample of 29 sites for additional data collection to characterize the practices and releases that led to the CERCLA listing. In most of these cases, tailings management contributed to releases. Other non-tailings releases resulted from exposed pits or adits, waste rock piles, leaching solutions, Bayer refining, flotation, and smelting processes. In many cases, releases were largely due to the direct discharge of wastes into the local environment, minimal containment efforts, or operator bankruptcy and abandonment. Additionally, most releases described in publicly available information occurred after closure of the mine or processing site, suggesting that the potential for releases and adequate monitoring remains a long-term issue after closure.

Contemporary Experience

Federal and state authorities, including EPA, Bureau of Land Management (BLM) and states, promulgated modern environmental regulations applicable to hardrock mining and primary processing operations throughout the 1970s, 1980s and 1990s. During this period, incremental requirements and applicability standards continued to bring hardrock mining and mineral processing operations into the period of contemporary mining.[9] Regulations under the Clean Water Act (CWA), for example, introduced waste management regulations and sought to end direct discharges into waterways, and federal and state reclamation requirements have sought to prevent operator abandonment.[10] In addition, mining and mineral processing facilities produce wastes regulated under both Subtitle C and D of the Resource Conservation and Recovery Act (RCRA).

Technological developments have resulted in a wide range of management strategies to prevent or mitigate environmental releases. The use of these engineering controls depends on the existing regulatory requirements, and factors such as operator sophistication and economics.[11,12] Also during the early to mid-20th century, a combination of economic and technological factors increased the amount of surface disturbance and waste generation relative to the scale of mining

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[9] This document uses the phrase “contemporary mining” to describe contemporary mining practices marked by technological sophistication and increased regulatory oversight.

[10] U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003). Accessed November 7, 2015, at: http://yosemite.epa.gov/R10/WATER.NSF/Sole+Source+Aquifers/hardrockmining.

[11] G. Hilson and B. Murck, "Progress toward pollution prevention and waste minimization in the North American gold mining industry," *Journal of Cleaner Production* 9 (2001), p. 405-415.

[12] G. Hilson, "Pollution prevention and cleaner production in the mining industry: an analysis of current issues," *Journal of Cleaner Production* 8 (2000), p. 119-126.

activities.[13] For example, cyanide heap leaching, which was developed relatively recently, exploits economies of scale to process low-grade ore.[14] The corresponding amount of waste rock and tailings being mined and deposited at a single site as a result of large-scale mining operations is increasing.[15] In turn, the environmental impact of mining and processing operations may be particularly high at larger facilities. For example, EPA found that in 2007, two percent of the estimated 294 mines with NPDES permits generated approximately 90 percent of the industry's discharges, accounting for pollutant toxicity.[16]

At least 52 mines and processors in the sample of currently operating facilities experienced permits exceedances, spills, seepages, fugitive dust, or other releases while using contemporary mining and processing practices. Releases occurred in the 1980s, 1990s, and after 2000. Similar to past releases, tailings management has continued to play a role in roughly half of the publicly documented releases. Releases occurred at both old and newly constructed tailings facilities. The review of mining and processing practices revealed the following concerns related to each practice:

- The environmental impacts of large mining operations, particularly surface mines, may include surface disturbances, fugitive dust, and contaminated mine waters from exposed mine walls and waste piles. Open pits and underground adits were the cause or the site of releases at a minimum of nine mining operations since 1980 in EPA's review.
- Despite no physical extraction of rock, non-entry mining can introduce hazardous contaminants into the environment. The threats are releases to adjacent groundwater and to surface soils and surface water from spills. Non-entry mining and related practices were responsible for 56 releases at two currently operating facilities.
- The primary environmental concerns associated with physical processing are the generation of fugitive dust and tailings, which can result in discharges to the environment. EPA's review revealed that at least four operations experienced continuous releases as a result of tailings from physical processing.
- Flotation processes may release flotation solution as well as tailings into the local environment, whose environmental risk profile is determined by their chemical

[13] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[14] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[15] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[16] U.S. Environmental Protection Agency, *Ore Mining and Dressing Preliminary Study Report*, EPA-820-R-10-025 (Washington DC, October 2011).

composition. Flotation contributed to releases at four operations since 1980 in EPA's review.

- In addition to the release of cyanide, discharges from cyanidation processes both during operations and after closure can also contain toxic elements. EPA found that cyanidation processes led to releases at 10 operations since 1980 in its review.
- Acid leach involves the use of sulfuric acid solutions. In addition to the threat sulfuric acid poses as a hazardous substance, the acid can mobilize other contaminants from surrounding material. EPA's review associated acid leaching with environmental releases at six operations since 1980.
- A major environmental concern with pyrometallurgical processes includes the release of sulfur dioxide and particulate matter containing lead, arsenic, and other airborne pollutants. Since 1980, six operations have experienced releases from roasting, smelting, and refining.
- The major environmental concern associated with the Bayer process is red mud, which can contain arsenic, chromium, and radium-226. Pyrometallurgical processing was responsible for releases at three facilities since 1980, according to EPA's review.

Most of these processes generate waste rock and/or tailings, with the exception of non-entry mining and pyrometallurgical processing. The disposal of waste rock and tailings requires long-term management and monitoring because of the potential for continued releases after facility closure. Of particular concern for waste management practices is the generation of mine-influenced water (MIW). MIW can contain process chemicals and additional mobilized contaminants.

No matter the extraction, processing, or waste management practice, facilities must transport, store, and dispose of material in the course of operations, e.g., through pipes and in ponds. Transportation and storage can result in releases due to leaks, seepage and spills. Pipe failure is a common source of release among currently operating facilities, although it did not lead to any Superfund sites in the non-operating sample. Process ponds contributed to releases in both the currently operating and non-operating samples, generally through seepage.

In addition to mining and processing activities, operator bankruptcy and abandonment were also associated with releases.[17] Commodity cycles affect the financial health of mine and processing

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[17] These findings reflect anecdotal evidence of the contributing factors to releases. In a literature review, no systematic reviews studied operator financial health in the hardrock mining sector and the creation of CERCLA liabilities. More broadly, however, studies have suggested that, in mining and in other industries, business owners respond to declining prices and profitability by cutting costs, thereby increasing the potential for accidents and environmental risk. The prices of gold, copper, and iron ore have demonstrated volatility in recent years. Price volatility increases the likelihood at any given time that mine operators may have to cut cost to respond to decreased profitability. For the connection between profitability and environmental performance in the gold mining industry, see Bruce Finnie, Jeffrey Stuart, Linda Gibson, and Fern Zabriskie, "Balancing Environmental and Industry Sustainability: A Case Study of the US Gold Mining Industry," *Journal of Environmental Management* 90 (2009): 3690-3699, p. 3692. For recent volatility of commodity prices, see Federal Reserve Economic Data, Federal Reserve Bank of St. Louis. Accessible at: https://fred.stlouisfed.org/.

facility owners/operators, which in turn may affect the environmental performance and likelihood of bankruptcy and abandonment.[18,19] This pattern can be especially relevant for smaller mining companies with relatively limited resources.[20]

The incidents from EPA's review related to all of the extraction, processing, and waste deposition practices described in this document. In these incidents, all of the practices either resulted in releases or contributed to increasing the volume or environmental harm of a release, or both. The effects of these releases ranged from minimal impacts with no known long-term effects to significant impairment to groundwater, surface waters, and air quality. Observed releases affected local wildlife, plants, and human populations. They varied in scale from sudden, catastrophic releases to continuous seepage into the local environment over the course of years and decades. The releases also occurred in the presence of engineering controls and mitigation strategies.

For more information on releases related to each practice, see the relevant chapters, below.

Limitations

A number of factors limited the inferences that can be drawn from data about releases at currently operating facilities:

- **Compliance:** Although environmental regulations establish a set of minimum standards, compliance with those regulations may not be fully achieved by individual facilities, making it difficult to determine actual practices. As described previously, even in the event of full compliance with the existing regulatory framework, the owner/operator of the facilities may not be following all available management practices designed to prevent and mitigate releases. The management practices described in the following sections represent available options rather than standard or required controls.
- **Permitted Releases:** Before the establishment of the current regulatory framework, all releases – even direct discharge of toxic material into the local environment – did not constitute illegal discharges. However, due to data limitations, the review of contemporary facilities considered only unpermitted releases or permit exceedances.
- **Releases after the Operation Period:** Releases occur during the post-closure and post-reclamation phases, which currently operating facilities have not yet reached.
- **Case Study Limitations:** The evaluation of past operations was drawn from CERCLA sites. Similarly, the review of currently operating facilities focused on case studies of

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[18] D. Laurence, "Establishing a sustainable mining operation: an overview," *Journal of Cleaner Production* 19 (2011), p.278-284.

[19] J.A. Brierley and C.L. Brierley, "Present and future commercial applications of biohydrometallurgy," *Hydrometallurgy* 59 (2001), p. 233-239.

[20] G. Hilson and B. Murck, "Progress toward pollution prevention and waste minimization in the North American gold mining industry," *Journal of Cleaner Production* 9 (2001), p. 405-415.

ongoing releases. For all sites and facilities, the review relied upon publicly available documents obtained online. No effort was made to obtain information in hard copy from state or local offices. Thus, the data for any mine or processor may not be complete, and this document does not attempt to characterize the statistical probability of releases in the overall hardrock mining and mineral processing universe.

Section 1: Current Mining and Mineral Practices

A. Surface and Underground Mining

B. Non-Entry (Solution) Mining and Ion Exchange Processing

C. Physical Processing, Gravity Processing, and Magnetic Processing

D. Flotation Processing

E. Cyanidation

F. Acid Leach, Solvent Extraction, and Electrowinning

G. Pyrometallurgical Processes

H. Bayer Process for Aluminum

A. Surface and Underground Extraction

Introduction

Mining is the process of extracting valuable minerals from their geologic source prior to beneficiation. The extraction of material from the earth during mining can be broadly divided into three categories: surface (open-pit) mining, underground mining, and solution mining (such as in situ leaching [ISL] or brine extraction). This document describes surface and underground mining, which are conventional mining methods that entail drilling, blasting, and/or removing earth or rock.

The environmental impacts of large mining operations, particularly surface mines, may include surface disturbances, fugitive dust, and contaminated mine drainage from exposed mine walls and waste piles.[21] At contemporary mines, economies of scale have favored surface mines, with a trend towards larger operations. As a result, the corresponding amount of overburden, waste rock, and tailings being mined and deposited at a single site is also generally increasing. Several sources, however, describe a renewed interest in underground mining as the availability of amenable near-surface deposits becomes exhausted.

While waste rock and other extraction wastes are generally exempted from the hazardous waste-management requirements of RCRA Subtitle C, federal and state mining programs contain requirements for how surface and underground mines should be reclaimed during and after operations. Moreover, the requirements vary greatly across states and specific operations. The CWA and delegated state programs also lay out requirements for water quality from mine drainage.

A review of non-operating CERCLA sites suggested that releases can occur during operations, as well as post-closure.

Past and Current Use

Historically, most metal ore extraction in the United States used underground mining; however, cost and the development of other technology have made it a less common extraction method. From the 1990s to the year 2000, the types of mines worldwide transitioned from 90 percent underground to 85 percent open-pit operations.[22] In the United States, surface mines produced approximately 97 percent of all non-coal ores by tonnage in 2007, with underground mines

[21] The main extraction wastes are overburden and waste rock; waste rock disposal is considered in Section 2.B. Tailings are waste from ore processing; disposal is considered in Section 2.C.

[22] M. Randolph, "Chapter 1.2.: Current Trends in Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1.

producing three percent of non-coal ores.[23] For metal ores specifically, surface mines produced almost 99 percent of ores, by tonnage.[24]

In metal mining, mergers and acquisitions have resulted in fewer operating companies, increased foreign ownership, and fewer and larger facilities.[25] The corresponding amount of waste rock and tailings being mined and deposited at a single site as a result of large-scale mining operations is also increasing. For example, large open-pit copper mines in the United States can generate up to a million tons of waste and ore daily, for decades.[26]

Currently, the industry is beginning to face engineering and economic constraints for size and depth of open-pit operations. Several sources describe a renewed interest in underground mining for this reason.[27] Some ore deposits may only be mined economically by underground mining methods. These deposits typically are deeper, and have geological features that require more targeted extraction methods.[28]

Technical Description

Both surface and underground mining generally entail drilling, blasting, and removing earth or rock. Economic factors, (e.g., commodity prices and production costs) and technical factors (e.g., the size, orientation, and geology of deposits) determine the extraction method used.[29]

In surface mining, commonly referred to as "open-pit mining," operators use heavy equipment to remove overburden materials that lie on top of ore deposits, e.g., non-valuable rock, soil, or surface features. After these overburden materials are removed, the ore deposits are extracted.

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[23] Michael Nelson, "Chapter 6.1.: Evaluation of Mining Methods and Systems," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1.

[24] Michael Nelson, "Chapter 6.1.: Evaluation of Mining Methods and Systems," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1.

[25] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[26] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[27] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002); M. Randolph. "Chapter 1.2.: Current Trends in Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, Volume 1; Steve Fiscor, "Major Open-Pit Copper Mines Move Underground." *Engineering and Mining Journal* (8 June 2010). Accessed October 9, 2015, at: http://www.e-mj.com/features/409-major-open-pit-copper-mines-move-underground.html#.VPDnDnzF9KI.

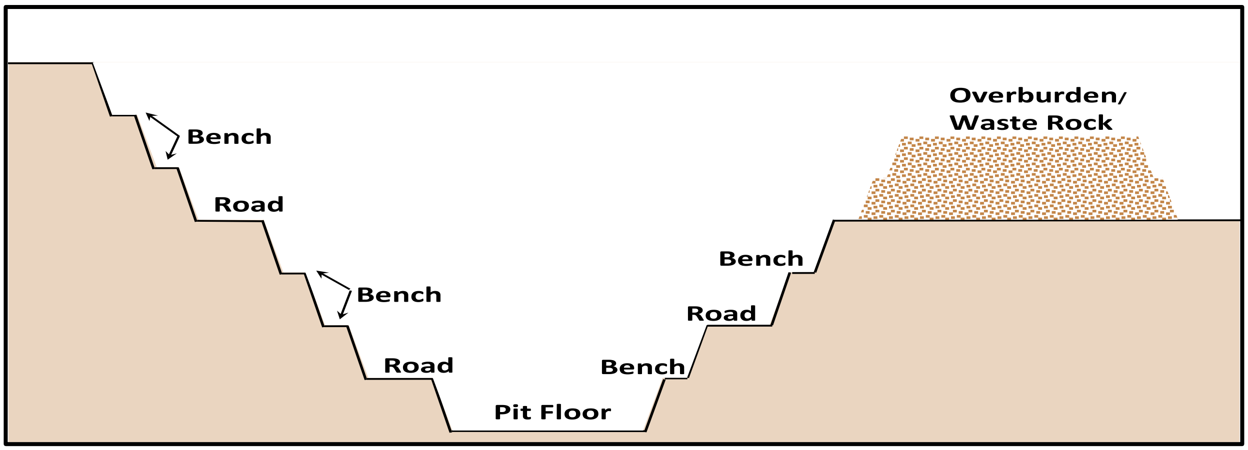
[28] Michael Nelson, "Chapter 6.1: Evaluation of Mining Methods and Systems," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1.

[29] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

Waste rock, which contains minerals at too low a concentration to be extracted profitably, may surround or be within the ore deposit, and is also removed. Generally, the geochemical properties of waste rock present additional environmental considerations for waste management.

Surface mining cuts one or more horizontal benches to extract the ore while dumping overburden and waste rock at dedicated disposal sites outside the final pit boundary.[30] Exhibit 1.A.1. shows a typical open-pit mine configuration. At some surface mines, the disposal of mine and processing wastes may occur in another area of an open pit, or in a dedicated storage facility on-site.[31] Less commonly, waste is used to backfill an already mined pit.[32]

Exhibit 1.A.1. Configuration of a Surface (Open-Pit) Mine



Underground mining methods are used when deposits occur deep beneath the earth's surface. Hardrock mines conducting underground operations commonly use nitrogen-based explosives to dislodge ore and waste. To reach the ore body, remove ore and waste, and provide ventilation, miners must excavate either a vertical shaft, a horizontal passageway (adit), or an inclined passageway.[33] Blasted ore is hauled away by trains, loaders, or trucks that either bring it directly to the surface, or transport it to a shaft where it is hoisted to the surface and sent to a crushing facility.

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[30] Andrew Wetherelt and Klass Peter van der Wielen, "Chapter 10.1: Introduction to Open Pit Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011).

[31] Andrew Wetherelt and Klass Peter van der Wielen, "Chapter 10.1: Introduction to Open Pit Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011).

[32] Andrew Wetherelt and Klass Peter van der Wielen, "Chapter 10.1: Introduction to Open Pit Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011).

[33] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

Because of economies of scale, large-scale surface mining techniques typically offer more efficient, productive, and safe ore recovery than underground methods, but require deposits to be relatively close to the surface and have uniform ore distribution.[34] On the other hand, deeper, less continuous deposits can only be mined economically by underground methods, which can target pockets of minerals more selectively. Underground mining may also be utilized if mining sites are subject to surface use restrictions.[35] Compared to surface mining, underground extraction operations require the pre-production installation of a great deal of infrastructure, in turn necessitating more careful planning and a larger initial capital investment.[36]

Potential Sources of Hazardous Substances

Both types of mining create large amounts of excavated material, with surface mining tending to generate greater amounts of waste rock. Surface mines generate dust, large piles of waste rock, and large, usually permanent holes in the earth's surface. Dust and waste rock – produced during both open-pit and underground mining – can release trace elements and other toxic substances. Waste rock and overburden piles are typically stored on-site, which may result in acid mine drainage (AMD)[37] or other MIW if exposed to stormwater, surface water or groundwater.[38] Exhibit 1.A.2. describes these causes of potential releases and management methods in more detail.

Because of the trend towards fewer and larger facilities, the environmental impact of mining and processing operations may also be concentrated. For example, EPA found that in 2007, two percent of the estimated 294 mines with NPDES permits generated approximately 90 percent of the industry's discharges, accounting for pollutant toxicity.[39]

[34] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[35] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[36] Nelson, "Chapter 6.1: Evaluation of Mining Methods and Systems," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011).

[37] "Acid mine drainage" is sometimes referred to as "acid rock drainage" to clarify that acid in an environment may be generated by processes other than human mineral extraction and processing activities. Because this document deals with mining and milling practices, it will use acid mine drainage, henceforth AMD.

[38] Tailings and other spent ore may also contribute to water contamination. These waste products of beneficiation and processing are discussed in Section 2.C.

[39] U.S. Environmental Protection Agency, *Ore Mining and Dressing Preliminary Study Report* , EPA-820-R-10-025 (Washington DC, October 2011).

Exhibit 1.A.2. Potential Releases Associated with Surface and Underground Extraction Methods

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Topographical impacts	Surface mines can result in significant alterations of natural landscapes and sometimes generate large piles of waste rock and typically permanent holes in the earth's surface. Subsidence from underground mining can result in the collapse of the overlying surface topography and pronounced changes at the surface.[40]	During design and planning phase, targeted extraction techniques such as selective mining and avoidance could be used to minimize topographic impacts.[41] While active, special handling techniques such as backfilling at underground mines can minimize and/or prevent subsidence.[42] At closure, backfilling open-pit mines, in-pit co-disposal of tailings and waste rock with dry or wet covers,[43] and revegetation of the mining area can lessen or minimize topographical impacts.[44]
Fugitive dust	Extraction can release toxic substances normally bound in rock. Before processing, a large amount of waste material is separated from mineral ore and frequently stored on-site in waste rock piles or tailings storage facilities. This waste may also contain chemicals introduced during separation processes, such as cyanide leaching agents. As a result, fugitive dust emissions containing toxic air pollutants may be released from surface mining pits, from piles of waste rock and tailings, or from the transportation of ore and waste materials.[45] For example, at gold mines, beneficiation processes such as milling (crushing) and autoclaving, as well as refining processes can generate atmospheric mercury emissions.[46]	For worker health and safety reasons during operations surface and underground mines control dust in conformance with MSHA regulations that require a variety of both wet and/or dry methods to reduce fugitive dust. This includes dust control for drilling, equipment and conveyors, haul roads, and any other mine features where fugitive dust resulting in worker health and safety may be an issue.[47] At closure dry or wet covers can be used to lessen or minimize fugitive dust emissions from mines.[48]

[40] F.K. Allgaier, ed., "Chapter 5: Environmental Effects of Mining," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[41] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1. Accessed December 4, 2015, at http://www.gardguide.com.

[42] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.1.

[43] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.7.

[44] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.

[45] Pramod Thakur, "Chapter 15.4: Evaluation of Mining Methods and Systems," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[46] G. Jones and G. Miller, *Final Report to EPA Region 9: Mercury and Modern Gold Mining in Nevada* (Washington, DC: U.S. Government Printing Office, 2005). Accessed January 13, 2015, at http://www.chem.unep.ch/mercury/Trade%20information/NRDC-NEVADABYPRODUCTRECOVERYREPORT.pdf.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	Coarse dust usually settles within a few hundred meters of the source. Smaller particle size fractions (PM10), however, can be carried by wind in dust clouds for great distances and may be deposited on or near populated areas. Because the dust may contain metals, human health and environmental problems may arise through direct inhalation, soil and plant deposition, or accumulation within a water body.	
Mine drainage – underground mines	Water flowing through underground mines can cause releases of mine water through mining openings.[49] Contact with exposed rock in mine shafts can transport contaminants and negatively impact soil and water quality. Mine water can have environmentally significant concentrations of metals and solids, elevated temperatures, and altered pH, depending on the nature of the ore body and local geochemical conditions. In addition, mine water can acidify over time as sulfide minerals are exposed to water and air, resulting in AMD. AMD, and MIW more generally, can cause significant threats to surface water and groundwater resources during active mining and for decades after operations cease.[50] For example, in 1993, the U.S. Forest Service (USFS) estimated that AMD impacted between five and ten thousand miles of domestic streams and rivers.[51] The need for costly water treatment can persist for decades after a mine has closed.[52] Depending on the hydrology of the site, the drainage may be discharged to groundwater or surface water. Acidic drainage also increases the leaching and mobility of some metals and trace elements.[53]	Grouting and other methods have been shown to be highly effective at reducing drainage from underground mines during operations.[54] Flooding can significantly block the flow of oxygen and prevent acid generation; however, soluble products can result in unacceptable water quality.[55] Seals can be used to create flooded conditions, however, if considerable hydraulic head is created rigorous engineering design is required.[56] Where discharges from underground mines result in unacceptable water quality conditions the mine discharge may be allowed to discharge naturally (e.g. out the mine portal) where it is captured and treated, or the discharge may be prevented by pumping the underground mine and maintaining the level. This technique is also used where underground mine discharges to groundwater require mitigation.[57] In the event the mine drainage requires treatment prior to discharge, either during operations or post-closure, a variety of active, passive and in situ mine drainage treatment techniques are potentially applicable.[58]

[47] Fred N. Kissell, *Handbook for Dust Control in Mining*, No.2003-147 (Washington, DC: U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, 2003). Accessed 4 December 2015 at: http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2003-147.pdf

[48] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.2.

[49] U.S. Environmental Protection Agency, DRAFT: *Mining Environmental Impact Statement Technical Report* (Washington, DC: U.S. Government Printing Office, 2013), p. 31.

[50] F.K. Allgaier, ed., "Chapter 5: Environmental Effects of Mining," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[51] U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995).

[52] U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995).

[53] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-R-94-013, Volume 2: Gold (Washington, DC: U.S. Government Printing Office, 1994). Accessed December, 2015, at: https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/iron.pdf.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Mine drainage – open-pit mines	Open-pit mine highwalls are prone to high rates of erosion and mass wasting. The exposed rock on the pit walls and the overburden may result in AMD or other MIW, often forming "pit lakes". Similar to underground mines, MIW can have environmentally significant concentrations of metals, other contaminants, and sediments, elevated temperatures, and altered pH.	Passive mitigation methods: [59] • Revegetation • Pit backfill to reduce exposure to air and water. For example, burying waste rock or using overburden material as backfill can reduce acid generation substantially, under proper geologic conditions. • Prevention of pit lake formation (e.g., drainage and treatment systems) • Diversion channels and ditches prevent AMD by intercepting and conveying runoff from undisturbed areas around active mining sites. [60] • Natural or constructed hydrological systems, including wetlands, limestone drains, water covers, and naturally occurring geochemical or biological processes • Bioremediation processes treating mine wastewater using natural acidophilic microbes. [61] Active: • Treatment of mining wastewater and separation of solids[62,63] • Pit lake pump/treatment/neutralization

[54] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.5.5.

[55] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.5.4.

[56] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.5.5.

[57] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.4, 4.2.2.2.

[58] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.5.

[59] R. Verburg, "Chapter 16.5: Mitigating Acid Rock Drainage," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[60] G. Hilson and B. Murck, "Progress toward pollution prevention and waste minimization in the North American gold mining industry," *Journal of Cleaner Production* 9 (2001), p. 405-415.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Mine drainage - Waste rock piles	The large quantities of overburden or waste rock material produced in surface or underground mining can be susceptible to weathering and leaching of contaminants resulting in discharge of hazardous materials. Waste rock produced from surface mines consists of non- mineralized and low-grade mineralized rock removed from above or within the ore body during extraction activities. Waste rock is typically disposed in large piles or dumps in close proximity and down-slope of the point of extraction. Regardless of the layout of the unit, waste rock dumps are generally constructed on unlined terrain, with underlying soils stripped, graded, or compacted depending on engineering considerations[64]	As part of mine design targeted extraction techniques such as selective mining and avoidance could be used to minimize mining of waste rock that could result in MIW.[65] As part of the waste rock disposal area design engineered barriers such as a liner can be utilized to collect seepage from waste rock resulting reduced seepage management requirements.[66] During operations special handling techniques such the addition of alkaline materials or amendments can be used to reduce potential for AMD.[67] At closure waste rock areas can be reclaimed using dry and wet covers to lessen or minimize discharges of MIW from waste rock piles. [68] In the event the mine drainage requires treatment prior to discharge, either during operations or post-closure, a variety of active, passive and in situ mine drainage treatment techniques are potentially applicable.[69]

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[61] D.B. Johnson, "Acidophilic Microbial Communities: Candidate for Bioremediation of Acidic Mine Effluents," *International Biodeterioration & Biodegradation* 35:13 (1995), p. 41-58; and T. Umita, "Biological mine drainage treatment." *Resources, Conservation and Recycling* 16 (1996), p.179-188; and United Nations. *1995 Industrial Commodity Statistics Yearbook - Production Statistics (1986-95)* (New York: United Nations, 1997).

[62] United Nations Environment Programme, United Nations Industrial Development Organization, and the World Bank Group, *Pollution Prevention and Abatement Handbook, Airborne Particulate Matter: Pollution Prevention and Control* (Washington DC: 1998), p. 235-239.

[63] G. Hilson,. "Barriers to Implementing Cleaner Technologies and Cleaner Production (CP) Practices in the Mining Industry: A Case Study of the Americas," *Minerals Engineering* 13:7 (2000), p. 699-717.

[64] A. Kent, “Waste Rock Disposal Design,” in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[65] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1.

[66] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.1.

[67] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.4.2.

[68] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2.

[69] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.5.

During ongoing operations, drainage, diversion, and wastewater treatment techniques can help to mitigate mine drainage, which may contain contaminants. During reclamation and closure, replacing the overburden as backfill and revegetation of the area can restore landscape features, prevent erosion, and reduce the potential for further water quality issues. Various factors, including the size and sophistication of mining operations, variation in regulatory requirements, and economic conditions may influence the preventative measures adopted at each site.[70] For example, all types of mining operations use culverts to intercept and convey runoff under access roads, stockpile areas, and structures. Some sources suggest, however, that many mining operations commonly undersize culverts or install them at too flat a grade to effectively carry away runoff.[71] In a survey of North American gold mines, some larger mining companies also reported neutralizing acidic mine drainage with lime, while no smaller mining companies indicated doing so.[72]

State and Federal Regulations

While BLM and USFS oversee mining activities on federal land, state-level mining regulations in many states apply to extraction operations on both private and public lands. BLM has required reclamation of lands since 1987, and USFS has required reclamation since 1974. Many states also maintain Memoranda of Understanding (MOU) with the federal government to share responsibility for management of mining on public lands.

While these federal and state regulations establish frameworks for reclamation and prevention of water contamination, performance standards vary greatly in their specificity and stringency. For example, BLM guidance states that particular mining claims may require appropriate mitigation and reclamation measures in plans of operations given anticipated potential environmental impacts, but that generally BLM land use plans do not prohibit certain mining practices through "zoning."[73] Mines opened after 1978 are required to treat effluent water, although the required treatment period after mine closure may not be specified. As such, a facility can close in full environmental compliance, but acid drainage and other MIW may remain potential concerns for more than 50 years.[74] While some states mirror BLM's management guidance, Montana Code Part 3 (Metal Mine Reclamation) details specific reclamation actions at sites that must be conducted and prohibits certain mining practices. As a result, not all mines may conduct

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[70] G. Hilson and B. Murck, "Progress toward pollution prevention and waste minimization in the North American gold mining industry," *Journal of Cleaner Production* 9 (2001), p. 405-415.

[71] C.D. Lidstone and A. Korte, "Chapter 16.4: Water and Sediment Control Systems," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[72] G. Hilson and B. Murck, "Progress toward pollution prevention and waste minimization in the North American gold mining industry," *Journal of Cleaner Production* 9 (2001), p. 405-415.

[73] U.S. Department of the Interior, Bureau of Land Management, *Surface Management Handbook* H-3809-1 (Washington, DC: U.S. Government Printing Office, 2012), Section 8.7.1, p. 8-14.

[74] U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995).

backfilling, pit lake treatment, or revegetation, or conduct reclamation activities concurrent with present operations.

While BLM surface mining regulations have not defined more specific standards for mine operation, reclamation, and closure,[75] congressional bills that also strive to define narrower standards for reclamation and water quality were introduced in 2009 and 2014, but were not ratified.[76]

Federal Regulations

Federal agencies have promulgated rules for extraction operations under various statutes and regulations. These include:

- **Land Disposal:** RCRA Subtitle C excludes mining extraction wastes, including waste rock and overburden, from being regulated as hazardous waste at the federal level.[77] Mining wastes may be subject to RCRA Subtitle D solid waste disposal requirements, which are regulated by the states.
- **Surface Management:** The BLM and the USFS permit and oversee mining activities on public federal lands. These agencies are charged with preventing "unnecessary and undue degradation" to public lands, and generally require the submission and approval of plans of operation for proposed activities, including an environmental assessment and reclamation plans. Other requirements include proper disposal, concurrent reclamation, and providing for post-mining monitoring, maintenance, and treatment.

Under 36 CFR Part 228 regulations, mining operations on USFS land must minimize adverse environmental impacts, by following approved plans of operation and complying with applicable Federal and state laws. Reclamation must be conducted at the earliest practicable time or within one year of conclusion of operations.

- **Discharges to Water:** Under the CWA effluent limitation guidelines (ELGs) for ore mining and dressing, mine drainage is subject to water quality standards for total suspended solids, pH, and specific metals.[78] These regulations also specify technology-based standards, and sometimes require National Pollutant Discharge Elimination System (NPDES) permits for these operations to incorporate certain best management practices.

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[75] A.P. Morriss, R.E. Meiners, and A. Dorchak, "Between a Hard Rock and a Hard Place: Politics, Midnight Regulations, and Mining," *Administrative Law Review* 55:3 (2003), p.551-606.

[76] HR 699, S. 796 (2009); HR 5060 (2014).

[77] The Bevill Amendment, passed by Congress in 1980, excluded "solid waste from the extraction, beneficiation, and processing of ores and minerals" from regulation under RCRA Subtitle C.

[78] 40 CFR Volume 50 Subpart J Section 440. In light of recent Supreme Court cases regarding the scope of waters protected under the Clean Water Act, applicability is further clarified in the proposed rulemaking EPA and Army Corps of Engineers at 79 FR 22187, "Definition of 'Waters of the United States' Under the Clean Water Act," accessed at: https://www.federalregister.gov/articles/2014/04/21/2014-07142/definition-of-waters-of-the-united-states-under-the-clean-water-act.

Where ELGs may not apply, technology-based limits are developed during the facility-specific permitting process. The NPDES program applies to both active and inactive mines, as well as abandoned mines where legally responsible owners or operators of point sources can be identified.

Runoff from waste rock piles may be regulated under NPDES stormwater permits when it is not commingled with process water or mine drainage.[79,80] Stormwater permits regulate stormwater contaminated by contact with material from mining activities, primarily requiring site-specific pollution prevention planning and/or implementation of mitigation practices.[81] These include treatment requirements, operating procedures, practices to control runoff, and monitoring. These rules do not cover all potential sources of water pollution. Mining pits protected by cover do not qualify as point sources from a "discrete conveyance," and do not fall under point-source requirements under the CWA.[82]

While EPA issues and oversees point-source discharge permitting under Section 402 of the CWA, the U.S. Army Corps of Engineers (USACE) issues "dredge and fill" permits under Section 404 of the CWA. Under CWA Section 404, mining operations may need to obtain a permit from USACE to address the discharge of dredged or fill materials into surface water, including wetlands. In areas with streams, wetlands, or lakes, excavation and construction activities may trigger this requirement. Some regulatory uncertainty exists regarding how mining overburden, slurry and tailings are regulated under the CWA because of different definitions of fill material used by EPA and USACE. Thus, Section 404 permits have been issued for mining operations outside of Section 402 NPDES permitting requirements.[83]

- **Air Emissions:** No federal air regulations specifically oversee fugitive dust concerns in mining operations, although the federal surface management regulations under BLM and USFS described above tend to require dust control practices. While these requirements are not discussed in the context of air toxics management, these measures are frequently incorporated into mining permits.

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[79] Seepage to groundwater is not considered a point source, and is not regulated under the Clean Water Act. The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[80] U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003). Accessed November 7, 2015, at: http://yosemite.epa.gov/R10/WATER.NSF/Sole+Source+Aquifers/hardrockmining.

[81] Best management practices for stormwater permits are described at 40 CFR 122.2.

[82] The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[83] C. Copeland, "Controversies over Redefining 'Fill Material' Under the Clean Water Act," *Congressional Research Service*, No. RL31411 (Washington, DC: U.S. Government Printing Office, 2013).

State Regulations

Over time, state mining reclamation laws shifted from focusing on coal mining operations only, to cover metals and ultimately surface and underground mining. The eight states with the most mining activity[84] have enacted surface mining management and reclamation laws, while all but Idaho regulate underground mining. Minnesota was the first to enact a surface mine reclamation requirement for minerals (in 1969), while Arizona was the last (in 1996). Other states with limited or no hardrock mining activity generally have not established regulatory programs for hardrock mining. For example, Texas has promulgated reclamation standards only for uranium operations. In Indiana, local authorities, rather than state agencies, establish requirements for land use and reclamation.

Non-Operating Sites and Currently Operating Facilities

Mine water may pass through open pits or underground adits and enter the local environment through runoff to surface water or seepage to groundwater. AMD is of particular concern because there is often a significant lag time between the start of mine operations and the observation of acidic drainage.[85] It may take at least five years for the oxidization of the acid-generating material and subsequent transportation into the local environment to take place.[86] A review of available documents revealed that releases related to extraction practices occurred at four of 29 non-operating sites and two of 70 currently operating facilities. This review separately considers releases from waste rock piles (an byproduct of surface and underground mining) later in this document, including 18 additional non-operating mines and five additional currently operating mine that experienced releases.[87]

This review of contemporary mines did not capture information characterizing the scope and efficacy of reclamation and closure practices. Improper and failed reclamation have been the basis for past CERCLA actions at hardrock mines, and remains a consideration for the environmental performance of contemporary mines.

Non-Operating Sites

Documents confirmed that 10 of the 29 non-operating mining and processing sites sampled for this review practiced surface and/or underground mining.[88] Two sites conducted exclusively surface mining, three sites conducted exclusively underground mining, and 5 sites conducted

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[84] Those states are Alaska, Arizona, California, Idaho, Minnesota, Montana, Nevada, Utah.

[85] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 2.

[86] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 8.3.4.

[87] For more detail, see Sections 2A and 2B on mine-influenced water and waste rock deposition.

[88] Note that it is likely, based on a review of mining and milling practices, that most if not all 29 non-operating sites reviewed practiced surface and/or underground mining. Documentation specifically described those practices at ten sites, however.

both. Activity at many of the sites extended back before the advent of major environmental legislation but continued into the 1980s and 1990s. At all 3 of the sites where surface or underground mining was responsible for the release of contaminant, the releases occurred as the result of acid mine drainage or mine-influenced water. It may take years to observe issues related to those contaminant vectors, so it is impossible to know if they are the result of past or more recent operations.[89]

- The **Captain Jack Mill** (EPA ID COD981551427) is a Superfund site in Ward, Colorado, that includes the workings of the Big Five Mine and White Raven mine, which included both open pits and underground adits, as well as the Captain Jack mill site. Gold and silver mining occurred at the site from 1861 through 1992. The EPA placed the site on the NPL in 2003 following the detection of antimony, arsenic, cadmium, copper, lead, manganese, thallium, and zinc in nearby Left Hand Creek. The primary source of contamination was AMD from the Big Five adit, which was constructed in the 19th century.[90]
- The **Summitville Mine** (EPA ID COD983778432) is a Superfund site in Rio Grande County, Colorado. It was active from 1875 through 1992. The mine had underground adits and open pits, and extracted gold, silver, and copper. The mine released MIW from various adits and pits at the site. This problem was accentuated by snowmelt and drainage that entered the mine's underground workings and flowed out through the adits before the adits were plugged.[91]
- The **Blackbird Mine** (IDD980725832) was a cobalt mine near Salmon, Idaho, that conducted surface and underground mining. It was operated intermittently from 1883 through 1982. AMD, in addition to the direct discharge of tailings into surface water in the mine's early operation, has released arsenic, cobalt, and copper into the local environment. The underground workings have been identified as a source of AMD.[92]
- One CERCLA site not in the sample, **Barite Hill/Nevada Goldfields** (EPA ID SCN000407714) was proposed for the NPL in 2008. The mine operated from 1989 to 1994. The operator, Nevada Goldfields, Inc., filed for bankruptcy in 1999 and abandoned the site.[93] The mining pits and ponds, and waste rock piles released arsenic, cadmium,

[89] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 2.

[90] U.S. EPA Region 8, Captain Jack Superfund Site Record of Decision (Washington, DC: U.S. Government Printing Office, 2008)

[91] U.S. Department of Health and Human Services, U.S. Public Health Service Agency for Toxic Substances and Disease Registry, Division of Health Assessment and Consultation. Public Health Assessment: Summitville Mine, Del Norte, Rio Grande County, Colorado (Washington, DC: U.S. Government Printing Office, 1997)

[92] U.S. Environmental Protection Agency Region 10, Office of Environmental Cleanup, Blackbird Mine Superfund Site Record of Decision (Washington, DC: U.S. Government Printing Office, 2003)

[93] "NPL Site Barite Hill/Nevada Goldfields, McCormick, South Carolina," U.S. Environmental Protection Agency. Accessed October 8, 2015: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0407714.

chromium, copper, lead, mercury, nickel, selenium, silver, zinc, and cyanide into the surrounding surface water and soil. The site has also experienced AMD.

Currently Operating Facilities

Documents confirmed that at least 51 facilities conducted surface mining, underground mining, or both, out of the sample of 70 currently operating facilities. Twenty-seven of the 51 facilities exclusively practiced surface mining, 20 exclusively practiced underground mining, and 4 practiced both mining methods. Of those 51 facilities, available documents and databases identified surface and underground mining as the source of contamination at three facilities

- **Kinross Crown Resources Buckhorn** (MSHA ID 4503615) is an underground gold mine located in north-central Washington state. The facility has been active since 2008. In 2008 and 2009, the mine committed 46 violations for discharging water containing sulfates and total dissolved solids in excess of permitted concentrations. The mine has discharged the contaminants into the groundwater, surface water, and springs and seeps. Causes of the discharges included the failure of the wastewater treatment system, seepage of mine water from the underground mine, and acid drainage from mine operation areas, including the underground workings. In 2012, the Washington Department of Ecology levied a $395,000 civil penalty against Crown, which was resolved through a 2013 Settlement Agreement. Water quality violations from the mine have continued in 2014 and 2015.[94]
- **Smoky Canyon Don** (MSHA ID 1001590) is an open pit phosphate mine located near Soda Springs, Idaho. Simplot has operated the facility since 1983. Selenium poisoning of local cattle created concern about Smoky Canyon and other nearby phosphate mines in the 1990s. In 2006, the USFS ordered a Non-Time Critical Removal Action to address the release of selenium and other constituent materials from Smoky Canyon Don. The selenium originated in overburden disposal areas, where operators deposit soil and other material that overlays ore deposits. The overburden disposal areas released selenium into both nearby Pole Canyon Creek and groundwater. The USFS and Simplot reached a Settlement Agreement/Consent Order to determine the nature and extent of the contamination, and a 2012 Engineering Evaluation/Cost Analysis to address additional potential pathways of contamination.[95]

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[94] Ann Maest, "Analysis of Water Quality Impacts at the Buckhorn Mountain Mine and Recommendations for Improvement: Final Report," prepared by Stratus Consulting, Inc., for the Okanogan Highlands Alliance (November 4, 2010). Accessed 16 September 2016 at: http://s3.amazonaws.com/zanran_storage/okanoganhighlands.org/ContentPages/2478359423.pdf; and Accountability for Buckhown Water Quality Deterioration: Violations Mount," Okanogan Highlands Alliance. Accessed 16 September 2016 at: http://www.okanoganhighlands.org/mine-monitoring/mine-seepage.

[95] Formation Environmental for J.R. Simplot Company. *Final: Smoky Canyon Mine Remedial Investigation/Feasibility Study – Remedial Investigation Report*. September 2014.

B. Non-Entry (Solution) Mining and Ion Exchange Processing

Introduction

Non-entry (in situ) mining methods recover materials of interest with little to no physical extraction of rock, obtaining elements dissolved in liquid solutions. In the United States, the most common of these methods are ISL, in which aqueous solutions (lixiviants) are injected into wells to help dissolve minerals of interest, and brine extraction, in which underground sources of water with naturally dissolved elements of economic interest (brine) are pumped to and processed at the surface. These methods of extraction and processing, primarily associated with uranium recovery, generate less waste material and cause fewer surface disturbances than surface or underground mining techniques.[96, 97] However, there are still significant environmental risks associated with mining methods such as ISL, particularly to local groundwater.[98]

Non-entry mining can release hazardous contaminants into the environment. The primary threats are releases to adjacent groundwater and to surface soils and water from spills. At the federal level, the Underground Injection Control (UIC) program under the Safe Drinking Water Act (SDWA) manages activities that may pose a risk to groundwater resources. For uranium mining, the EPA and the Nuclear Regulatory Commission (NRC) have also promulgated a variety of technical standards for uranium facilities that address health, safety, and environmental issues under the Atomic Energy Act of 1954 and the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA).

In part because of the relatively recent expansion in use of this extraction method, limited evidence from non-operating Superfund sites was available to illustrate these practices or associated releases. Other publicly available sources, however, have documented releases related to ISL and its attending processing practices at currently operating uranium facilities. This is of significant concern, given the inherent risks associated with underground injection of lixiviants and the severity of potential risks that may stem from uranium recovery practices.

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[96] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[97] B. Dershowitz, "Discrete fracture network modeling in support of in situ leach mining," *Mining Engineer Magazine* (November 2011). Accessed October 2, 2015, at: http://www.golder.com/eu/en/modules.php?name=Publication&sp_id=241&page_id=212&service_id=50.

[98] A recent proposed rulemaking under UMTRCA focused on the potential environmental and health risks posed by ISL uranium mining. See U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, *Draft Report: Economic Analysis: Proposed Revisions to the Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings Rule (0 CFR Part 192)* (November 2014).

Past and Current Use

In the United States, non-entry mining operations recover uranium, copper, potash, magnesium, and lithium.[99] For uranium operations, this technique is also referred to as "in situ recovery." The most common applications are ISL operations to extract uranium in Texas, Wyoming, and Nebraska and copper in Arizona.[100] ISL operations in Texas and Wyoming have extracted water-soluble salts and uranium since the 1960s.[101] In the 1980s, ISL became increasingly prevalent for recovering uranium. Conventional surface and underground uranium mines and the mills that processed the extracted ore were phased out; only one conventional mill processing ore from two mines remains in the United States.[102] Processing practices associated with uranium – such as ion exchange, resin stripping, precipitation, and drying – now take place almost exclusively at or in association with ISL facilities.[103]

Brine extraction has been used to recover lithium in Nevada and zinc in California, while the Frasch process (which uses hot, high-pressure water) recovers sulfur in Texas and Louisiana. Bore-hole mining, which uses water jets to break rocks into slurry that is pumped to the surface, has also recovered phosphate in Florida and uranium in Wyoming.[104]

Non-entry methods for other minerals have been more difficult to implement, as only certain types of deposits are amenable to these methods.[105] ISL requires highly permeable sandstones, such as those containing uranium, while other non-entry methods leverage naturally existing deposits of minerals dissolved in groundwater. Copper ISL operations primarily recover minerals

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[99] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[100] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[101] T. Albanese and J. McGagh, "Chapter 1.3: Mining: Future Trends in Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1.

[102] "Uranium Mining Overview," World Nuclear Association, updated June 2015. Accessed January 21, 2016, at: http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview/.

[103] "Uranium Mining Overview," World Nuclear Association, updated June 2015. Accessed January 21, 2016, at: http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview/.

[104] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[105] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

where prior mining has created sufficient permeability for leaching solutions to contact ore minerals, although these operations experience lower recovery rates.[106]

Technical Description

Non-entry (in situ) mining recovers materials of interest with little to no physical extraction of rock, recovering elements dissolved in solutions. Because it eliminates the need to remove and manage extraction wastes, non-entry mining is typically more economical than conventional excavation techniques, and is particularly feasible for low-grade deposits.[107]

ISL dissolves metals and other minerals from rocks by first injecting chemical lixiviants through a drilled well.[108] Minerals of interest react with the solution and are mobilized from the rock into the solution, referred to as a pregnant solution. The pregnant solution is then extracted from a recovery well. After the minerals of interest have been removed from the solution, the lixiviant may be reused. The parent material containing the ore and the geochemical behavior of the commodity itself determine the type of lixiviant used. Alkaline lixiviants (generally sodium carbonate and sodium bicarbonate) are predominant in North America. Compared to acidic lixiviants (such as sulfuric acid) that are more powerful dissolving agents, alkaline lixiviants create less environmental impact.[109]

Brine extraction is a related technique to ISL that injects water only, or pumps to the surface brines containing naturally dissolved materials.[110] For example, heated water is used to recover magnesium.[111] For aqueous deposits containing naturally dissolved materials, the brine solution is pumped to the surface and evaporated. The Frasch process (used to recover native sulfur) and

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[106] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[107] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[108] A lixiviant is a liquid medium used in hydrometallurgy to selectively extract the desired metal from the ore or mineral. It assists in rapid and complete leaching. The metal can be recovered from it in a concentrated form after leaching. See American Institute of Mining Engineers, *Transactions of the American Institute of Mining Engineers* 49 (Princeton: Princeton University, 1917), p. 617.

[109] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[110] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[111] "In Situ Recovery Facilities," U.S. Nuclear Regulatory Commission, last updated March 31, 2015 .Accessed from: http://www.nrc.gov/materials/uranium-recovery/extraction-methods/isl-recovery-facilities.html.

bore-hole mining also use water to dissolve, melt, or break apart rock, and then pump the solution or mixture to the surface.[112]

ISL extraction is particularly amenable to previously mined ore bodies, which allow for increased contact with rock, although new technologies in non-entry mining also use fracturing or drilling to enhance contact with ore.[113] For example, the most successful practice for copper ISL generally takes place in previously mined ore bodies, which allows lixiviants to contact rubble of lower grade wall rock.[114] Through injection wells, lixiviant solution floods underground mine caverns and extracts ore left in the walls of mining operations. The saturated brine is pumped out through extraction wells. The solution from ISL or brine extraction is pumped aboveground through separate recovery wells and is processed in surface treatment facilities using ion exchange columns, precipitation reactions, or solvent extraction.[115]

In Situ Leaching and Ion Exchange Processing of Uranium

Ion exchange represents the most common method of follow-on processing after recovery of uranium-bearing solution. For uranium, a lixiviant composed of a native groundwater from the host aquifer, a complexing reagent to leach the uranium, and an oxidant is injected into a well. The leach liquor oxidizes and dissolves the uranium, creating a pregnant solution.[116] Extraction wells pump the solution to the treatment plant, where it passes through ion exchange resins, binding the constituent uranium compounds to the resins in the form of a uranyl carbonate.[117] Additional oxidant and reagent are added to the barren leach solution, which is recycled to the

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[112] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[113] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[114] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[115] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[116] "In Situ Leach (ISL) Mining of Uranium," World Nuclear Association, updated July 2014. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium/.

[117] It is also possible to capture the uranium compounds through a liquid ion exchange, or solvent extraction system. In the United States, however, "[ion exchange] is used in the vast majority of ISL operations" and "ion exchange operations [are] used by most if not all in situ operations." See "In Situ Leach (ISL) Mining of Uranium," World Nuclear Association, updated July 2014. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium/; and "Identification and Description of Mineral Processing Sectors and Waste Streams: Uranium," U.S. Environmental Protection Agency, last updated November 15, 2012. Accessed January 11, 2016, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/part1.pdf.

leach circuit.[118] A concentrated chloride salt solution then strips the uranium compound from the resins.[119] Hydrochloric acid is applied to remove the carbonate from the uranium, at which point hydrogen peroxide precipitates the uranium out of the salt solution.[120] The uranium crystals are then filtered, dried, and roasted to create uranium oxide concentrate, or "yellowcake," a product containing about 80-85% uranium by mass.[121] The resultant yellowcake is shipped to a separate facility for conversion to nuclear reactor fuel.[122]

Usually, a uranium ISL facility encompasses the uranium source, injection wells, an ion exchange circuit, the precipitation circuit, and the roasting circuit. It is possible, however, for some processing stages to occur at a remote uranium source. The ISL leach liquor can be pumped to a central processing facility where it undergoes ion exchange, sometimes alongside leach liquor from conventional ore that has undergone heap leaching.[123] Alternatively, a remote facility may include an ion exchange circuit and ship the loaded resins to a central precipitation and roasting facility.[124]

Potential Sources of Hazardous Substances

Because non-entry mining does not physically remove rock, this method of extraction generates less solid waste material and causes fewer surface disturbances than surface or underground mining techniques.[125,126] Non-entry mining therefore presents a lower risk of harms associated

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[118] "In Situ Leach (ISL) Mining of Uranium," World Nuclear Association, updated July 2014. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium/.

[119] "Identification and Description of Mineral Processing Sectors and Waste Streams: Uranium," U.S. Environmental Protection Agency, last updated November 15, 2012. Accessed January 11, 2016, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/part1.pdf.

[120] "Identification and Description of Mineral Processing Sectors and Waste Streams: Uranium," U.S. Environmental Protection Agency, last updated November 15, 2012. Accessed January 11, 2016, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/part1.pdf.

[121] "Uranium Mining Overview," World Nuclear Association, updated June 2015. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview/.

[122] Note that ion exchange is also used to extract uranium in phosphate processing; uranium and phosphate rock often occur together, and ion exchange can remove radioactive elements from phosphate to be sent for fertilizer processing. See International Atomic Energy Agency, *The Recovery of Uranium from Phosphoric Acid* (Conference Held at Vienna, Austria, March 16-19, 1987).

[123] "Uranium Mining Overview," World Nuclear Association, updated June 2015. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview/.

[124] "In Situ Leach (ISL) Mining of Uranium," World Nuclear Association, updated July 2014. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium/.

[125] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[126] B. Dershowitz, "Discrete fracture network modeling in support of in situ leach mining," *Mining Engineer Magazine* (November 2011).

with solid waste or surface disturbances. ISL methods, however, may cause groundwater contamination from chemical lixiviants, or from dissolved metals or co-occurring elements such as thorium, radium, radon, arsenic, vanadium, zinc, selenium, and molybdenum.[127] The type of reagent can increase the potential risk of contamination. For example, ISL using acidic reagents changes the pH of groundwater and dissolves other minerals and metals in addition to the target uranium. In contrast, the alkaline bicarbonate reagents used in the United States selectively dissolve uranium, with much lower risk of contamination.[128] As of 2009, no remediation of an ISL operation in the United States for which data are available had successfully returned the aquifer to baseline conditions. More than half of those ISL operations experienced uranium and selenium levels above the baseline even after groundwater restoration efforts.[129]

Some of the impacts associated with non-entry mining can be avoided with proper engineering and management before the commencement of mining activities.[130] Monitoring and maintenance limit the release of lixiviants and mobilized metals from ISL operations. Practices to limit the environmental impact of ISL include baseline environmental data collection, pilot operations with test liquids, and installation of monitoring wells.[131,132] This includes the proper engineering of well and surface infrastructure, analysis of background groundwater chemistry, and analysis and testing of aquifer hydrology and geology using pump tests. In addition, monitoring wells are installed farther down gradient from the well cluster to monitor groundwater and ensure that lixiviant is not escaping the mining area.

Ensuring a net inflow of clean water into the capture zone can also prevent injection solution from escaping due to pressure gradient differences.[133] After ISL and related processing operations, reclamation entails the removal of all radiological hazards (for uranium extraction operations), capping and covering of drill holes, and restoration of groundwater to pre-ISL

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[127] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[128] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[129] Susan Hall, "Groundwater Restoration at Uranium In-Situ Recovery Mines, South Texas Coastal Plain," Open-File Report 2009-1143, *U.S. Geological Survey* (Talk presented in Keystone, CO, on 11 May 2009).

[130] Gavin Mudd, *An Environmental Critique of In Situ Leach Mining: The Case Against Uranium Solution Mining* (Melbourne: Australian Conservation Fund, 1998). Accessed October 2, 2015, at: http://www.sea-us.org.au/pdfs/isl/no2isl.pdf.

[131] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities* (Washington, DC: U.S. Government Printing Office, 2009). Accessed 2 October 2015 at: http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1910/v1/intro-ch1.pdf.

[132] B. Dershowitz, "Discrete fracture network modeling in support of in situ leach mining," *Mining Engineer Magazine* (November 2011).

[133] B. Dershowitz, "Discrete fracture network modeling in support of in situ leach mining," *Mining Engineer Magazine* (November 2011).

conditions.[134,135] Depending on geologic and hydrologic conditions, however, metals and leach solution may seep into surrounding aquifers post-closure.[136]

Non-entry mining that does not use chemical lixiviants may cause leakage of water, but this can often be safely discharged into nearby surface water. Drilled wells from any of these methods, however, may cause the surface lands to sink or shift (subsidence).[137,138]

Groundwater restoration techniques include direct cleaning or "self-cleaning."[139] Direct cleaning, which is the most common method in the United States, uses reverse osmosis, washing and restoration with natural groundwater, or cleaning by precipitation. Self-cleaning uses natural attenuation, but this process may take place over tens to hundreds of years. It can be accelerated through increasing groundwater flow rates, or by introducing substances to encourage bacterial bio-remediation. Alternatively, a "groundwater sweep" restoration pumps water from the mined aquifer to a deeper aquifer, to surface evaporation ponds, or to the next aquifer subject to ISL.[140]

Even with the application of the above mitigation strategies, the majority of ISL mines experience higher levels of selenium and uranium in the groundwater after restoration than before mining started.[141]

Exhibit 1.B.1. provides more detail about the sources of potential releases from non-entry mining, as well as the management methods that may mitigate these risks.

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[134] B. Dershowitz, "Discrete fracture network modeling in support of in situ leach mining," *Mining Engineer Magazine* (November 2011).

[135] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities* (Washington, DC: U.S. Government Printing Office, 2009).

[136] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[137] J.T. Laman, "Chapter 10. Solution Mining and In-Situ Leaching," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[138] Land subsidence is a geological phenomenon that occurs when large amounts of groundwater are withdrawn from rock formations, causing rocks to fall cave or fall in. Source: "Land Subsidence," U.S. Geological Survey, updated August 20, 2015. Accessed October 2, 2015, at: http://water.usgs.gov/ogw/subsidence.html

[139] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[140] Susan Hall, "Groundwater Restoration at Uranium In-Situ Recovery Mines, South Texas Coastal Plain," Open-File Report 2009-1143, *U.S. Geological Survey* (Talk presented in Keystone, CO, on 11 May 2009).

[141] Susan Hall, "Groundwater Restoration at Uranium In-Situ Recovery Mines, South Texas Coastal Plain," Open-File Report 2009-1143, *U.S. Geological Survey* (Talk presented in Keystone, CO, on 11 May 2009).

Exhibit 1.B.1. Potential Releases Associated with ISL and Ancillary Processes[142,143,144]

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Lixiviant contamination of surrounding groundwater(horizontal excursion)	The primary concern associated with ISL is contamination of surrounding groundwater (excursions). Excursions can occur due to poor design of the wellfield (pattern of injection, recovery, and monitoring wells). The wellfield needs to be carefully designed to follow the flow of groundwater. Unpredicted aspects of aquifer geology (e.g., fractures in the parent material) can also lead to poor wellfield design and excursions. Depending on the parent material, gypsum, calcite, or other minerals can form precipitates in the lixiviant eventually plugging the aquifer, wells, or pumps. In addition, some lixiviants can lead to increased microbial growth (by introducing previously limiting elements), which can also clog rock pores and impact pressure. Failure of an injection or recovery well as well as pore clogging can alter the pressure gradient in the underground aquifer being mined, leading to excursions. Leaks caused by the lixiviant are most commonly associated with acidic lixiviants, which can corrode well infrastructure. Mechanical failure can occur if exploratory or other wells not in use in the mining operation are present and not properly plugged or if pipe joints have separated or casings have ruptured. These types of excursions are especially difficult to detect and remedy.	Pump tests are usually conducted before mining commences to ensure proper understanding of the groundwater hydrology and aquifer chemistry and geology. If these tests are conducted with realistic pumping pressures and conditions they can allow for the analysis of potential problems. The use of alkaline lixiviants in the United States also decreases the likelihood of gypsum, calcite and other mineral formations. EPA guidelines for Class III wells mandate that more liquid be removed from the recovery well than was input in injection wells (typically 0.5 percent to 5 percent more) in order to minimize the possibility of excursion. Monitoring wells allow for quick detection of any excursions so that they can be cleaned up. The plugging of wells is essential. Well shafts are typically encased (e.g., Polyvinyl chloride [PVC] pipe) to avoid leakage and vertical flow.
Surface spills of lixiviant	Flash floods can lead to failures during such extreme weather events if surface equipment is not properly engineered. Surface spills can also occur during processing or during "wash downs" of processing plant equipment.	Proper engineering of surface equipment is necessary to account for any potential extreme weather events. In addition, to prevent surface exposure at processing facilities, most are designed with curbed concrete floors and drainage systems. The drainage systems are designed to collect any spilled fluids and transfer them to surface retention ponds.
Leaks from storage/disposal of mining fluids in evaporation ponds	As lixiviant becomes degraded with continued cycling through the mine, fresh lixiviant needs to be introduced. Spent mining solutions are temporarily stored in surface retention ponds before final disposal (e.g., processing and re-injection underground for fluids or disposal at an NRC-licensed site for solids, for uranium recovery). During this time there is a	Alkaline lixiviant is the only type currently used in the US and typically produces lower levels of impurities in mined fluids. This enhances recycling of lixiviant and decreases the amount of wastewater that needs to be stored and managed above ground.

142 "Environmental Impacts of Different Uranium Mining Processes," Alberta Environment, last updated 2008. Accessed October 2, 2015, at: https://extranet.gov.ab.ca/env/infocentre/info/library/8178.pdf.

143 Gavin Mudd, *An Environmental Critique of In Situ Leach Mining: The Case Against Uranium Solution Mining* (Melbourne: Australian Conservation Fund, 1998).

144 U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities* (Washington, DC: U.S. Government Printing Office, 2009).

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	risk of leakage at these surface ponds. Surface ponds can also be breached during flash floods or other storm events.	Proper pond lining can limit the chance of leaks. This design could include two separate layers of chemically unreactive plastic (e.g., high density polyethylene) with sand or another porous material between them. Placing a layer of clay underneath that liner would further protect against leaching should a leak occur. Retention ponds must also have leak detection systems.
Release of radon and other radioactive elements from leaching fluids	Radon is a known carcinogen and can be released during both the construction of ISL wellfields as well as during ion exchange and related processing. In addition, substantial quantities of radon can be released from spent mining fluids being temporarily stored in surface retention ponds.	Because of the short half-life of radon (3.8 days) in the environment no active management typically occurs for this type of pollution. Rather, dilution and degradation in the atmosphere is typically sufficient. Limited air monitoring is normally conducted.
Release of radioactive materials in dust	Particulates can accumulate around ion exchange facilities. These can include uranium dust or salts that can precipitate out of the lixiviant. These are then introduced into the environment through ventilation of the processing facility.	Processing typically contains dust collection systems that capture these particulates and in most cases collects 99% of contaminants.
Reclamation of mining fluids	After an ore body has been fully mined groundwater must be restored to pre-mining quality. As such, groundwater in the mined area is chemically treated to remove excess contaminants above background levels. This is done in a four step process: removal of contaminated water by ceasing injection and continuing removal, pre-treatment via reverse osmosis, chemical treatment to precipitate and immobilize contaminants, and re-introduction of the treated water. Undocumented background levels and insufficient treatment can lead to groundwater contamination. Most ISL mining zones are situated between two low permeability clay deposits. Clay has a high surface area and the unique ability to store large amounts of cations. As such, potentially harmful chemicals from the lixiviant can attach to clay particles and persist there (potentially beyond remediation activities) until the groundwater chemistry favors their eventual release.	A substantial suite of background data should be collected before the commencement of mining activities. These data should include measurements of sulfates, pH, total salinity, uranium, radium, arsenic, molybdenum, and selenium. Proper chemical treatment of mining fluids requires a strong understanding of the unique chemistry and geology of each ISL site.
Transport and disposal of solid radioactive wastes	The processing of lixiviant from ion exchange and subsequent circuits produces solid radioactive wastes, such as spent resin and tank sediments. These wastes are typically stored in surface retention ponds until they, along with residual pond sludge, need to be transferred to NRC-licensed disposal facilities once the mine is decommissioned.	Proper transport and disposal of solid waste according to existing regulations should avoid these impacts.

State and Federal Regulations

Both federal and state regulatory programs manage non-entry mining.

The UIC program under the federal SDWA and delegated state programs regulate the construction, operation, permitting, and closure of injection and extraction wells in order to protect underground sources of drinking water.[145] Additionally, EPA's New Source Performance Standards (NSPS) prohibit mines and mills using ISL methods from discharging process wastewater, unless annual precipitation exceeds annual evaporation.[146] ELGs under the CWA also specify requirements for pH, total suspended solids, chemical oxygen demand, and specific contaminants.[147] For non-entry mining facilities that discharge to surface waters, these requirements are incorporated into permits.

For uranium ISL facilities, the predominant commodity extracted using non-entry mining, the EPA and the U.S. Department of Energy (DOE) have also promulgated a variety of technical standards for uranium facilities that address health, safety, and environmental issues under the Atomic Energy Act of 1954 and UMTRCA of 1978. The standards include the removal of contaminated equipment and material, cleaning up evaporation ponds, plugging wells, backfilling and recontouring disturbed areas, revegetation, and site radiation surveys. Waste products from processing are regulated by the NRC and must be disposed of in a licensed disposal facility.[148]

While UMTRCA has historically regulated only traditional uranium mill processes, EPA promulgated a proposed rule establishing ground water restoration and monitoring requirements at ISL facilities under UMCTRA. These requirements, which would be implemented by the NRC, include preliminary characterization of aquifer geochemistry and groundwater conditions, corrective action in the case of contamination, wellfield restoration, and post-operational monitoring for groundwater quality. These baseline and restoration tests would address 13 of the most important chemicals affecting groundwater pollution: arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, nitrate (as nitrogen), molybdenum, radium, total uranium and gross alpha particle activity.[149]

The Office of Surface Mining, the U.S. Department of the Interior, and individual states regulate conventional surface or underground uranium ore extraction. On the other hand, the NRC regulates

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[145] "Underground Injection Control," U.S. Environmental Protection Agency, Under Ground Injection Control Program, last Updated November 2013. Accessed October 2, 2015, at: http://water.epa.gov/type/groundwater/uic/index.cfm.

[146] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 5: Uranium (Washington, DC: U.S. Government Printing Office, 1994).

[147] 40 CFR 440 (CWA effluent limitation guidelines: ore mining and dressing point source category).

[148] J. Kyle, D. Maxwell, and B. Alexander, "Chapter 11.5: In-Situ Techniques of Solution Mining," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[149] 80 FR 4156. Vol. 80, No. 16, 4156. January 26, 2015. *Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings; Proposed rule.* Accessed 28 June 2016 at: https://www.regulations.gov/document?D=EPA-HQ-OAR-2012-0788-0001

uranium processing and concentration. ISL uranium facilities, even standalone ISL facilities that transport recovery fluid to a separate plant for further processing, fall under the purview of the NRC.[150] The NRC requires the restoration of aquifer quality to the use class prior to mining operations. NRC and delegated "agreement states" issue licenses for uranium in situ solution mining and conduct environmental reviews of the construction, operation, and decommissioning of uranium ISL facilities.[151]

State Regulations

In Texas, after ISL operations are completed, all radiological hazards must be removed and groundwater must be restored to pre-operational conditions under Title 30 Section 331.107(b). The Texas Commission for Environmental Quality (TCEQ) regulates underground injection wells through the Underground Injection Well Permit Program, under Chapter 27 of the Texas Water Code. 30 TAC 331.104 requires that a restoration table in the UIC permit that establishes levels for key constituents, meeting the pre-existing conditions for groundwater of the mining zone.

In situ uranium operations in Texas are required to obtain a radioactive material license, which TCEQ issues. The Texas Railroad Commission regulates the exploration phase of ISL uranium mining through a permit program. Wyoming, South Dakota, and New Mexico also regulate uranium ISL operations under state-specific mining programs, which require reclamation and bonding.[152] In Arizona, copper ISL facilities must also obtain an Aquifer Protection Permit (APP), use best demonstrated control technology, and maintain state aquifer water quality standards.

Non-Operating Sites and Currently Operating Facilities

Most non-entry mining sites in the United States are uranium production and processing facilities, and ISL for uranium is a relatively new extraction method. Thus, scant documentation about non-operating ISL sites exists. In more recent years, the use of ISL and related processing methods has expanded such that only one conventional uranium mine and associated mill operation remains in the United States. Releases related to ISL have increased concomitant to that expansion, as reflected in the sample.

Non-Operating Sites

ISL is a relatively new mining method. As such, none of the reviewed documents recorded any releases associated directly with ISL or non-entry mining. However, alkaline leach and ion exchange,

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[150] "Uranium Recovery: What We Regulate," U.S. Nuclear Regulatory Commission, updated February 10, 2015. Accessed January 21, 2016, at http://www.nrc.gov/materials/uranium-recovery.html.

[151] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for In Situ Leach Uranium Milling Facilities* (Washington, DC: U.S. Government Printing Office, 2013). Accessed October 2, 2015, at: http://www.nrc.gov/materials/uranium-recovery/geis.html.

[152] U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for In Situ Leach Uranium Milling Facilities* (Washington, DC: U.S. Government Printing Office, 2013).

the processing method for ISL solution, have been used to process uranium for much longer. Documents confirmed that three of the 29 non-operating mining and processing CERCLA sites sampled for this review extracted metals or minerals through alkaline leach and ion exchange.[153] Tailings ponds failure and the attendant discharge of tailings liquid and other process wastewaters contributed to releases at two of the sites.

- The **Homestake Mining Co.** site (EPA ID NMD007860935) was a uranium mill near Milan, New Mexico, from 1958 to 1990. From the start of activity, the mill operated an alkaline leach-caustic precipitation process to produce yellowcake. Material for the mill originated at five underground uranium mines and a satellite ion exchange facility in Ambrosia Lake, New Mexico. Operators disposed of waste from milling in two on-site tailings ponds. In 1983, EPA placed the site on the National Priorities List due to elevated selenium and uranium concentrations in the local aquifer and nearby groundwater wells. Homestake, the operator of the mill, installed a groundwater injection system to clean the aquifer, but the contamination plume ultimately traveled off-site. Remediation, monitoring, and maintenance continued for at least twenty years after mill closure.[154]
- The **United Nuclear Corporation** (EPA ID NMD30443303) operated a uranium mine mill near Church Rock, New Mexico. The underground mine was active from 1967 to 1982, the mill was active from 1977 to 1982. The site included a leaching circuit and an ion exchange plant. United Nuclear disposed of processing waste in tailings disposal cells. In 1979, the dam for the South tailings disposal cell breached and released 93 million gallons of liquid into the Rio Puerco, contaminating the local aquifer and releasing uranium and radium into local surface water and soils.[155]

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[153] Cyprus Tohono Mine (EPA ID AZD094524097), Homestake Mining Co. (NMD007860935), and United Nuclear Corp. (NMD030443303).

[154] U.S. Environmental Protection Agency, Region 6, *Record of Decision: Homestake Mining Company Radon Operable Unit, Cibola County, New Mexico* (Washington, DC: U.S. Government Printing Office, 1989); "Homestake Mining Co. Superfund Site Description," U.S. Environmental Protection Agency, from September 8, 1993, Federal Register Notice. Accessed January 13, 2012, https://nepis.epa.gov/Exe/ZyNET.exe/20013X6J.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000015%5C20013X6J.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL. and Center For Disease Control, Agency for Toxic Substances and Disease Registry, Health Consultation: Homestake Mining Company Mill Site, Milan, Cibola County, New Mexico (Washington, DC: U.S. Government Printing Office, 2009).

[155] U.S. Environmental Protection Agency, "Action Memorandum: Request for a Non-Time-Critical Removal Action at the Northeast Church Rock Mine Site, McKinley County, New Mexico, Pinedale Chapter of the Navajo Nation," sent September 29, 2011; and U.S. Environmental Protection Agency, Region 6, *Five-Year Review Report: Second Five-Year Review Report for the United Nuclear Corporation Ground Water Operable Unit* (Washington, DC: U.S. Government Printing Office, 2003).

Currently Operating Facilities

Documents confirmed that three of the 70 currently operating facilities reviewed use ISL extraction and/or related processing practices,[156] and three facilities use brine extraction.[157] Of those six, two uranium ISL facilities experienced releases due to ISL practices and related operations.[158]

- **Uranium One Willow Creek** (no MSHA ID) encompasses two distinct sites: the Irigaray processing plant located in Johnson County, Wyoming, and the Christensen Ranch satellite operation, located in Campbell County, Wyoming. Uranium One is the site's owner and operator. Initial activity at the site began at the Irigaray site in 1978; operations from the currently active wells and processing facilities began in 2010. Both sites are in situ uranium recovery mines with ion exchange plants and precipitation circuit. The yellowcake drying/packing circuit is located at Irigaray.

  Since the start of the most recent round of production and processing, the Nuclear Regulatory Commission has filed event reports on at least 34 spills, leaks, or other releases, originating from injection fluid, recovery fluid, production fluid, evaporation ponds, and disposal wells. For example, on August 19, 2011, 7,000 to 10,000 gallons of sodium chloride brine overflowed a tank and spilled. On January 2, 2014, 77,000 gallons of production fluid containing from 11.9 ppm uranium to 13.6 ppm uranium spilled due to a frozen, burst pipe. On August 14, 2015, 492 gallons of in situ recovery fluid containing 11.2 ppm uranium spilled. In addition to those liquid releases, on September 9, 2014, two sampling operators at the Honeywell Uranium Refinery in Illinois opened a barrel of yellow cake shipped from the Willow Creek facility. Willow Creek had not allowed the yellowcake sufficient time to dry, leaving decomposing uranyl peroxide hydrates that pressurized the barrel. Upon opening, the barrel ejected yellowcake in a three foot radius.[159]

- Production at the **Lost Creek** ISL mine (no MSHA ID) in Sweetwater County, Wyoming, operated by Ur-Energy, began in 2013, although limited mineral exploration and activity had taken place at the site dating back to the 1960s. Currently, the facility extracts uranium through six contiguous in situ recovery projects. The recovery fluid is then piped to a processing plant,

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[156] Energy Fuels White Mesa (4201429), Uranium One Willow Creek (no MSHA ID), and Lost Creek (no MSHA ID).

[157] Rockwood Lithium (No MSHA ID), Florida Canyon Mine (MSHA ID 2601947), and Intrepid Potash East/West (No MSHA ID).

[158] A third facility outside of the currently operating sample, the Cogema Mining ISL facility in Bruni, Texas, may have experienced releases during decommissioning activities in 1997-1998, but publicly available documentation is limited regarding these incidents. See, for example, Texas Department of Health. Bureau of Radiation Control, "Radioactive Material Spill – Cogema Mining, Inc. – Bruni, Texas," *Summary of Incidents for Second Quarter 1999* (Dallas: U.S. Government Printing Office, 1999).

[159] "Site Summary: Willow Creek Uranium Recovery Project," Nuclear Regulatory Commission, updated July 15, 2015. Accessed January 21, 2016, at http://www.nrc.gov/info-finder/materials/uranium/licensed-facilities/christensen-ranch.html; and "Issues at Operating Uranium Mines and Milles – Wyoming, USA," World Information Service on Energy, updated September 2, 2015. Accessed September 11, 2015, at http://www.wise-uranium.org/umopuswy.html.

where it undergoes ion exchange, resin stripping, precipitation, and filtering/drying/packaging. Since the resumption of operations in 2013, the Nuclear Regulatory Commission has filed event reports on at least 22 spills, leaks, or other releases of waste water, injection fluid, and production fluid. Further, in December 2013, the state of Wyoming ordered a halt of operation at Lost Creek because the facility failed to maintain the bleed in its injection/recovery ratios, making it possible for contaminated groundwater to escape the mine site.[160] The Nuclear Regulatory Commission issued three additional violations for exposing workers to yellow cake dust in November 2014.[161]

[160] A "bleed" refers to the need to extract more water than is injected into the aquifer, thus ensuring an inflow of groundwater to the mine site instead of an outflow from the mine site. See "In Situ Leach (ISL) Mining of Uranium," World Nuclear Association, updated July 2014. Accessed January 21, 2016, at http://www.world-nuclear.org/info/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium/.

[161] Douglass H. Graves and Steve E. Cutler, *Preliminary Economic Assessment of the Lost Creek Property, Sweetwater County, Wyoming* (Bozeman, MT: Prepared by TREC, Inc., for Ur-Energy, Inc., 2015); and "Issues at Operating Uranium Mines and Milles – Wyoming, USA," World Information Service on Energy, updated September 2, 2015. Accessed September 11, 2015, at http://www.wise-uranium.org/umopuswy.html.

C. Physical Processing and Gravity and Magnetic Separation

Introduction

Physical processing and gravity and magnetic separation techniques are used widely across the mining industry. Physical processing (or comminution) is a standard first step in many other mineral processing activities. It includes crushing and grinding procedures that reduce the size of ore fragments, either in preparation for market specifications about particle size (such as in the case of iron ore), or to allow further processing (as is the case for base and precious metals).[162] The primary environmental concerns associated with physical processing are the creation of fugitive dust and tailings, which can result in discharges to the environment. Subsequent processing, such as cyanidation, may be associated with process chemicals that can pose additional environmental concerns. Standard industry practice to control dust involves a combination of wetting agents, dust collection and filtration. Containment (typically within a concrete area) is required if process chemicals are employed. After physical processing, magnetic and gravity separation methods exploit differences in the physical properties of crushed particles to isolate minerals of interest. While few regulations specifically regulate physical processing or gravity and magnetic separation, potential environmental discharges from these processes are addressed by many larger regulatory frameworks across federal and state programs.

A review of a sample of non-operating sites and currently operating mining facilities did not indicate evidence of releases specifically related to gravity and magnetic separation. Rather, past waste management practices (e.g., open dumping) and streambed excavation methods contributed to releases. The physical process of grinding and crushing liberates substances previously bound in rock, however, which may be released to the environment in the air and in MIW.

Past and Current Use

Separation and liberation of ore from waste material have been a part of mining operations since the very beginning of the industry. Comminution (encompassing all crushing, milling, and grinding procedures) is used widely across hardrock commodity sectors in the United States, as most ore requires some level of physical processing, either in preparation for further processing or to meet product requirements. Physical processing techniques have experienced few fundamental changes in recent years. Significant improvements in throughput and efficiency have taken place, however. For example, computer models of grinding circuits have reduced waste and use of chemicals by tailoring grinding operations to specific ore characteristics.[163] In addition, currently used equipment has the

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[162] J. Mosher, "Chapter 14.2: Crushing, Milling, and Grinding," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[163] Earle A. Ripley, Robert E. Redmann, and Adèle A. Crowder, *Environmental Effects of Mining* (Delray Beach, Fla: St. Lucie Press, 1996).

ability to mill a broader range of material, while historic grinding mills processed fairly specific particle size ranges.

Gravity separation has historically played a role in recovering gold from placer deposits; currently operating gold operations still use it to recover gold that is not bound to other minerals. The heavy minerals industry (e.g., titanium, zirconium, and hafnium commodities) also uses it extensively for recovery of minerals such as ilmenite, rutile, leucoxene and zircon, as well as to separate coarse-grained metal sulfides.[164,165] Dense medium separation, in which particles sink or float in a liquid medium, also finds applications in iron-ore processing.[166]

Recent improvements in technology have increased the applications of magnetic separation, as the availability of much stronger magnetic fields allows use of this process on additional commodities. For years, magnetic separation was used mainly in the dry separation of minerals from beach sand deposits and to remove tramp iron that can damage equipment, but more recently it has also been used to treat fines at iron-ore operations and remove paramagnetic wolframite and hematite from tin ores.[167,168]

Technical Description

Physical processing prepares ore for further processing and is commonly the first step in beneficiation. Gravity and magnetic separation isolate valuable material from waste either for further processing, or more rarely, as a final product. Unlike many other types of processing that require intensive use of chemicals, gravity and magnetic processing usually involve minimal use of additives. However, process chemicals may be added during physical processing in preparation for other steps (e.g., leaching or flotation).

Physical Processing

Physical processing is the first step in the beneficiation process for most commodities, including those that require further magnetic or gravity separation. It usually involves a multi-step reduction process that entails multiple procedures, from the initial crushing of rock to the ultra-fine grinding required by certain industrial mineral processing applications. The initial steps are generally carried out by crushers, which reduce ore from the originally mined size to the point where grinding can be

[164] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[165] N. Subasinghe, "Chapter 14.4: Gravity Concentration and Heavy Medium Separation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[166] Barry A. Wills and Tim Napier-Munn, *Wills' Mineral Processing Technology, Seventh Edition: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery*, Seventh Edition (Oxford: Butterworth-Heineman, 2006).

[167] P. Iyer, "Chapter 14.6: Magnetic and Electrostatic Separation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[168] Barry A. Wills and Tim Napier-Munn, *Wills' Mineral Processing Technology, Seventh Edition: An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery*, Seventh Edition (Oxford: Butterworth-Heineman, 2006).

undertaken, and screens or other sizing equipment. The crushing process is usually dry, and involves multiple iterations to get the particles to the desired size.[169]

Grinding is the next step, undertaken once the particles are small enough. It is usually carried out as a wet process, with the addition of water (and other process chemicals, such as those for subsequent flotation and leaching processing) to create a slurry.

Gravity Processing

After physical processing, gravity separation uses differences in density to separate heavy minerals and metals from lighter waste material (gangue). Gravity concentrators such as pulsating screens, shaking devices, or flowing film separators create particle movement, causing heavier particles to sink and lighter particles to rise closer to the surface. Gravity separation devices generally use water to create a slurry, and require feed material that is of uniform size. Other fluid media of varying densities, such as solution containing suspended metal particles, can be used to adjust the process to various ore types. These processes tend to be inexpensive to operate and rarely use harmful chemicals in slurry feeds, resulting in relatively less environmental damage than many other processing techniques.[170]

Magnetic Processing

Magnetic processing (either wet or dry) uses differences in magnetic strength to separate out particles. Magnetic pulleys, typically installed in the conveyor head, are commonly used devices.[171] High-intensity magnetic separators, like induced-roll magnetic separators and lift-type magnetic separators, separate materials of varying magnetism by deflecting them with high-intensity magnets. Some magnetic separators, such as the Jones separator, also work on wet feed streams.[172] While magnetic processing primarily separates iron ores, it can also be used for heavy mineral sands (e.g., zircon, ilmenite and rutile).

The electrostatic separation process relies on differences in electrical conductivity rather than magnetic strength. In this dry process, medium-sized particles fall through a high-voltage static field and are diverted by the natural conductivity of the material. This method has generally been used to recover valuable heavy minerals from beach-sand deposits.[173, 174]

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[169] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[170] N. Subasinghe, "Chapter 14.4: Gravity Concentration and Heavy Medium Separation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[171] P. Venkatraman, F. Knoll, and J. Lawver, "Chapter 7: Magnetic and Electrostatic Separation," in *Principles of Mineral Processing*, eds. Maurice C. Furstenau and Kenneth N. Han (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2014).

[172] P. Iyer, "Chapter 14.6: Magnetic and Electrostatic Separation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[173] P. Venkatraman, F. Knoll, and J. Lawver, "Chapter 7: Magnetic and Electrostatic Separation," in *Principles of Mineral Processing*, eds. Maurice C. Furstenau and Kenneth N. Han (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2014).

Potential Sources of Hazardous Substances

Physical processing and gravity and magnetic separation generally require few chemical additives and thus have a relatively small potential for adverse environmental impacts from process chemicals.[175] Dust from crushed and ground rock is a primary source of adverse effects during physical processing, posing concerns for human health as well as air and water quality.[176] Water application and enclosure minimize risks from dust created during physical processing, often in conjunction with exhaust ventilation systems that help capture and remove dust before it is expelled from exhaust fans.[177]

Additionally, tailings produced from physical processing and magnetic and gravity separation can contain trace elements and may present health and environmental concerns. Most stand-alone operations (e.g., those where no additional processing is performed) that use only physical processing and gravity and magnetic separation produce tailings that have few hazardous substances, and thus have a lessened potential for environmental harm.[178]Facilities may dispose of wastes from various processes in the same waste management units, however, with the resulting mixture containing more hazardous constituents than tailings from gravity or magnetic separation alone.[179]

The primary method of managing environmental discharges from tailings is to pump the mineral slurries to tailings ponds, where the solids settle to the bottom and consolidate, allowing the cleaned liquid above to be recycled to the plant or discharged. In cases where chemicals are added to the slurry to facilitate additional processing, or where wastes from other processes are co-mingled, tailings ponds may have to be lined with plastic liners or covered to prevent leaks or overflow.[180] Section 2.C. discusses tailings management in more detail.

Exhibit 1.C.1. describes these potential releases in more detail.

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[174] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[175] D. Van Zyl and J. Johnson, ed., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[176] This is particularly important during the grinding process, since the size range of particles undergoing grinding is often in the respirable category. Any particles smaller than 60 micrometers can be suspended in the air and subsequently be inhaled or deposited in nearby ecosystems.

[177] Department of Health and Human Services, Center for Disease Control and Prevention, *Dust Control Handbook for Industrial Minerals Mining and Processing* (Washington, DC: U.S. Government Printing Office, 2012).

[178] D. Van Zyl and J. Johnson, ed., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[179] U.S. Environmental Protection Agency, *Mineral Processing Facilities Placing Mixtures of Exempt and Non-Exempt Wastes in On-site Waste Management Units: Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 1995). Accessed October 30, 2015, at: https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/mixtures.pdf.

[180] D. Dahlstrom, "Chapter 14.7: Dewatering Methods," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

Exhibit 1.C.1. Potential Releases Associated with Physical, Gravity, and Magnetic Processing

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Fugitive dust	Comminution can release large quantities of dust and fine particles. Dust may also escape from uncovered tailings facilities. Coarse dust usually settles within a few hundred meters of the source. Smaller particle size fractions (PM10), however, can be carried by wind in dust clouds for great distances and may be deposited on or near populated areas. Because the dust may contain trace elements or other harmful substances (e.g. asbestos or silica), human health and environmental problems may arise through direct inhalation, soil and plant deposition, or accumulation within a water body.	The following practices help to manage fugitive dust from physical, gravity, and magnetic processing activities[181]: • Application of water through wet spray systems • Enclosure of the dust source • Exhaust ventilation • Maintenance of a slight negative pressure for enclosed grinding equipment, which ensures that any air leakage will flow into and not out of the equipment.
Tailings	During gravity separation and magnetic separation, the valuable product is separated from the waste material and the waste material is eliminated as tailings. In most cases, the tailings do not use chemical additives, but problems such as MIW with acidic properties or trace elements may arise. If these tailings are not disposed of correctly, runoff and seepage can contaminate groundwater and surface water. If facilities dispose of tailings in impoundments alongside wastes from other processes, the resulting mixtures may also contain higher concentrations of potentially harmful substances.	Proper construction of tailings ponds allows potential contaminants to settle out of water before it discharges. When chemicals are added to the slurry, leak detectors and linings must be employed to ensure that no harmful substances are discharged to the environment.[182, 183] As part of mine design targeted extraction techniques such as selective mining and avoidance could be used to minimize mining of ore resulting in tailings that could result in MIW.[184] As part of the tailings disposal facility design engineered barriers such as a liner can be utilized to collect seepage from tailings resulting in reduced seepage management requirements.[185]

[181] Department of Health and Human Services, Center for Disease Control and Prevention, *Dust Control Handbook for Industrial Minerals Mining and Processing* (Washington, DC: U.S. Government Printing Office, 2012).

[182] D. Dahlstrom, “Chapter 14.7: Dewatering Methods,” in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 2.

[183] For more details on the construction of tailings ponds in regards to specific site and tailings characteristics, see D. Van Zyl, J. Johnson, “Chapter 8.5: Tailings Disposal Design,” in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[184] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1.

[185] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.1.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
		Another technique is production of paste or dry dewatered tailings to reduce potential for MIW.[186] During operations special handling techniques such the addition of alkaline materials or amendments can be used to reduce potential for AMD from tailings.[187] At closure tailings areas can be reclaimed using dry and wet covers to lessen or minimize discharges of MIW. [188] In the event the mine drainage requires treatment before discharge, either during operations or post-closure, a variety of active, passive and in situ mine drainage treatment techniques are potentially applicable.[189]

[186] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.8.

[187] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.4.2.

[188] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2.

[189] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.5.

State and Federal Regulations

While few regulations pertain specifically to physical, gravity and magnetic processing, many broader regulatory frameworks across the industry address these practices at the state and federal level. Section 2.C.4. discusses regulations applicable to tailings management in more detail.

Federal Regulations

Potential releases from physical processing and gravity and magnetic separation for certain ores is regulated under the ELGs outlined by the CWA. For example, the CWA does not allow concentrations of pollutants over a certain level for tungsten mills processing by physical methods, or titanium mills beneficiating by electrostatic, magnetic or physical methods. In addition, it sets limitations on sediment in wastewater discharge and guidelines for treatment for certain types of mining such as placer mining, which often uses gravity separation.[190] As a result, most direct-discharging ore mining and dressing facilities use settling or precipitation treatment.[191] Where ELGs may not apply, technology-based limits are developed during the facility-specific permitting process. The NPDES program applies to both active and inactive mines, as well as abandoned mines where legally responsible owners or operators of point sources can be identified.

While the Clean Air Act (CAA) and RCRA do not directly address fugitive dust or tailings from physical processing and gravity and magnetic separation, state and local governments implement State Implementation Plans (which manage particulate matter emissions) under CAA as well as solid waste management guidelines under RCRA Subtitle D. Under RCRA Subtitle D, the federal government provides information and policy guidance to support state and local governments, such as criteria for the safe re-use of tailings in other industrial applications.[192] In situations where facilities combine tailings with mineral processing wastes that exhibit hazardous characteristics, the waste mixtures may also fall under RCRA Subtitle C regulations. The MSHA also specifies inspections and safety standards for impoundments, retention dams, and tailings ponds, and the Federal Emergency Management Agency (FEMA) is charged with administering a national dam safety program that includes tailings structures.[193]

Mining operations on federal land are subject to additional regulation. According to BLM Section 3809 rules, mining operations must prevent unnecessary or undue degradation, which

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[190] 40 CFR 424 (ferro-alloy manufacturing); 40 CFR 436 (mineral mining and processing); 40 CFR 440 (ore mining and dressing).

[191] U.S. Environmental Protection Agency, *Technical Support Document for the 2004 Effluent Guidelines Program Plan* EPA-821-R-04-014 (Washington, DC: U.S. Government Printing Office, 2004).

[192] U.S. Environmental Protection Agency, *Final Rule: Criteria for the Safe and Environmentally Protective Use of Granular Mine Tailings Known as "Chat"* Docket EPA-HQ-RCRA-2006-0097 (Washington, DC: U.S. Government Printing Office, 2007). Accessed October 30, 2015, at: https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/html/index-4.html

[193] 30 CFR Part 57, Subpart S. For more information, see: "Dam Safety Standards and Technical Guidance," MSHA. U.S. Department of Labor. Accessed October 30, 2015, at: http://www.msha.gov/DamSafety/DamSafetyTechGuidance.asp.

includes managing all tailings, rock dumps, deleterious material or substances and any other waste produced from mining operations.[194] Tailings from physical processing and gravity and magnetic separation fall under this general regulation as waste produced by mining operations and are thus subject to the permitting and approval requirements for operations on BLM lands. Dust suppression measures are usually employed as standard operating procedures under BLM-approved Plans of Operations.

In some cases, specific types of ores are subject to additional regulations. For example, UMTRCA mandates special closure designs for uranium mill tailings ponds to prevent radon gas releases.[195] While gravity and magnetic separation are not typically used for uranium ore, physical processing is generally a first step in beneficiation for uranium.

State Regulations

As with federal BLM surface management guidance, state mining regulatory programs may incorporate practices such as dust control, backfilling, erosion control and revegetation into state mining permits. Some states specifically regulate dust created by mining. For example:

- **Alaska** has a prohibition on fugitive dust, requiring anyone engaging in an industrial activity or construction project to take reasonable precautions to prevent particulate matter from being emitted into the ambient air, and prohibiting emissions harmful to human health or welfare and to animal or plant life. [196]
- **Rhode Island**'s Air Pollution Control Regulation No. 5 on fugitive dust prohibits any person to use matter capable of releasing dust in any way that could cause airborne particulate matter to travel beyond the property line of the emission source without taking adequate precautions to prevent particulate matter from becoming airborne.[197]
- **Michigan**'s Natural Resources and Environmental Protection Act requires crushers, grinding mills and screening operations to be sprayed with water or a surfactant solution, utilize choke-feeding, or be treated by an equivalent method in accordance with an operating program designed to significantly reduce the fugitive dust emissions to the lowest level that a particular source is capable of achieving.[198]
- **Utah**'s Environmental Quality and Air Quality regulations require any person owning or operating a mine to minimize fugitive dust.[199]
- **California's** Asbestos Airborne Toxics Control Measure (ATCM) requires all

[194] 43 CFR Part 3809

[195] UMTRCA, PL 95-604

[196] 18 AAC 50.045(d), 18 AAC 50.110

[197] R.I. Air Pollution Control Regulation No. 5, authorized pursuant to R.I. Gen. Laws § 42- 17.1-2(s) and 23-23

[198] Natural Resources and Environmental Protection Act 451 of 1994. 324.5524 Fugitive dust sources or emissions.

[199] R307-205-7, R307-205-8

construction, grading, quarrying, and surface mining operations in areas known to naturally contain asbestos to take specified control measures during road construction and maintenance operations.[200]

- **Idaho's** Permit by Rule for Non-Metallic Mineral Processing Plants requires that facilities that crush or grind any nonmetallic mineral or rock register with the Idaho Department of Environmental Quality (IDEQ). The rule sets electrical generator rules, fugitive dust control standards, monitoring, and record keeping.[201]

Several state regulations manage tailings, although in some cases tailings from gravity and magnetic separation that have no chemical additives are excluded from regulation. In addition, some regulations only address tailings from specific types of ore. For example:

- **Alaska**'s Department of Environmental Conservation Solid Waste Disposal Permit makes tailings from hardrock mines and tailings from placer mines that have been amalgamated or chemically treated subject to the State solid waste management general standards and requirements, which usually necessitate pre-operational, operation, and post-closure monitoring.[202]Tailings that have not been chemically treated (which is often the case with gravity and magnetic separation), however, are not subject to regulation.
- **Montana**'s Hard Rock Mining Reclamation Act specifies that milling operations are subject to permitting, requiring a detailed description of the design, construction, and operation of the mill, tailings, and waste rock disposal facilities, and best management practices are expected in the disposal of tailings and other waste.[203]
- **Nevada**'s regulations on hazardous materials require that tailings from active and inactive uranium and thorium mills are disposed of in a safe and environmentally sound manner.[204]

Non-Operating Sites and Currently Operating Facilities

The available documents indicate that four out of 29 non-operating sites used gravity separation and 18 out of 29 used physical processing. It is likely, however, that most of these sites used physical processing in conjunction with or in preparation for other types of beneficiation, even though the available documents do not specify this. Out of 57 current sites, available documents indicate that four use gravity separation and 30 use physical processing. Again, though, it is likely that most of these sites employ some physical processing methods.

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[200] 17 CCR 93105

[201] IDAPA 58.01.01.795–799

[202] Title 18 AAC Chapter 60- Solid Waste Management

[203] ARM 17.24.101-ARM.17.24.189

[204] NRS 459.300-NRS459.370

Non-Operating Sites

A review of CERCLA sites reveals that many non-operating sites used physical processing and magnetic or gravity separation alongside other processes. Evidence indicated that waste management practices, rather than the beneficiation practices, largely contributed to environmental contamination:

- The **Ely Copper Mine** (EPA ID: VTD988366571) in Vershire, Vermont, conducted copper mining and processing from 1821 to 1920.[205] Copper ore was processed using physical techniques, with flotation and roasting activities taking place in the early 20th century. According to state and federal authorities, mine drainage and runoff from exposed tailings piles caused elevated metal concentrations in soil, surface water, and groundwater.
- The **Torch Lake** site (EPA ID MID980901946) processed copper ore for over a century in Houghton County, Michigan, beginning in 1868.[206] The site extracted copper by stamping, crushing, grinding, and driving the rock through meshes. Gravity separation further refined the crushed rock. Ammonia leaching processes began in 1916. The operators dumped both tailings and spent leaching liquor into Torch Lake, which served as a repository for tailings throughout the site's history. Approximately 200 million tons of tailings were dumped into Torch Lake during the site's years of operation. In the 1970s, tests found that Torch Lake had high concentrations of copper and other trace elements, which were attributed to waste disposal practices.
- The **Anaconda Company Smelter** site (EPA ID MTD093291656) processed copper ore from 1884 until 1980.[207] Initial steps crushed ore and used gravity separation to concentrate ore in preparation for roasting and smelting, Tailings from gravity concentration were discharged onto the floodplains of Warm Springs Creek. In the 1980s, the operator agreed to conduct remedial actions because groundwater in the vicinity of

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205 "Waste Site Cleanup & Reuse in New England: Ely Copper Mine," U.S. Environmental Protection Agency. Accessed October 28, 2015: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0102065.

206 U.S. Environmental Protection Agency, *Superfund Record of Decision: Torch Lake, MI* (Washington, DC: U.S. Government Printing Office, 1992). Accessed October 28, 2015: http://nepis.epa.gov/Exe/ZyNET.exe/91001NR1.txt?ZyActionD=ZyDocument&Client=EPA&Index=1991%20Thru%201994&Docs=&Query=%28tailings%29%20OR%20FNAME%3D%2291001NR1.txt%22%20AND%20FNAME%3D%2291001NR1.txt%22&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C91THRU94%5CTXT%5C00000021%5C91001NR1.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=3.

207 U.S. Environmental Protection Agency, *EPA Superfund Record of Decision: Anaconda Co. Smelter* (Washington, DC: U.S. Government Printing Office, 1994). Accessed October 28, 2015: http://www.mtech.edu/academics/clsps/ptc/sciencesocietysuperfund/pdfs/archival_materials/anaconda_archives/anaconda_rod/b_smelter.pdf.

the site contained cadmium levels that exceeded federal SDWA Maximum Contaminant Levels (MCLs).

Evidence for one site also indicated the use of physical processing and gravity separation without the use of other process chemicals. Site documents for the Pioneer Pit mine CERCLA site (EPA ID CAN000905978) did not indicate any chemical use at this site; the mine instead processed gold placer deposits using sluice boxes (gravity separation). Releases of sediment resulted from hydraulic excavation methods (which use high pressure water jets to break up stream beds), not processing activities.

Publicly available information did not directly tie known releases to these processing methods. All four non-operating sites operated before the promulgation of the CWA, which now prevents the use of the waste management practices (e.g., open dumping) and excavation methods that contributed to contamination at these sites.

Currently Operating Facilities

Little evidence was available to shed light on the incidence and types of releases from the currently operating facilities, and there is no evidence specifically tying releases to physical, magnetic or gravity separation. Because available documentation did not always discuss non-chemical processing methods, this review focused on facilities that were identified to use only physical processing and gravity or magnetic separation.

Four facilities extracted heavy mineral sands at placer operations: Iluka Resources in Virginia (MSHA IDs 4407250, 4407222, and 4407221),[208] DuPont Titanium in Florida (MSHA ID 800225), Southern Ionics North Mine in Georgia (MSHA ID 901230), and Southern Ionics South Mine in Georgia (unknown MSHA ID). These facilities did not appear to utilize chemical processes, and no evidence suggested releases of hazardous substances. At least two of these facilities (Iluka Resources and DuPont Titanium) used gravity separation, electromagnetic and electrostatic separation methods.

[208] "Heavy Mineral Sands," Virginia Department of Mines, Minerals, and Energy. Accessed July 31, 2015, at: https://www.dmme.virginia.gov/dgmr/heavyminsand.shtml.

D. Flotation Processing

Introduction

Flotation processing separates valuable minerals from waste material using differences in water-repellency, either natural or chemically induced. It is often used in conjunction with gravity concentration, and the concentrate resulting from metallic ore flotation is commonly treated by smelting. The primary environmental concerns stem from the tailings produced by flotation processes and their geochemical contents, which can result in MIW. While the CWA addresses releases to surface water directly from flotation processes, potential environmental impacts from flotation tailings are not addressed by the CWA because they are generally considered non-point sources. Instead, they are addressed by groundwater frameworks across federal and state programs.

A review of a sample of non-operating sites and currently operating mining facilities revealed several releases related to facilities that engaged in flotation processing. Causes were generally due to geochemical contaminants in flotation tailings, which resulted in discharges to groundwater or surface water.

Past and Current Use

The first documented use of flotation occurred in 1877 for the processing of graphite from ores. Until about 1920, flotation was a relatively inefficient process requiring large quantities of oil or fatty materials to cause the desired separation. During this period, the primary reagents used for flotation included oils, soaps, ketones, esters, aldehydes, lime and soda ash. Over time, chemicals employed in other industries were adapted for use in flotation processing of mineral ore, substantially decreasing the amount of reagent necessary for separation and making the process more effective. Primary reagents used for flotation during the period from 1921 to 1950 included xanthate, chelating agents, fatty acids, petroleum sulfonates and primary amines.

By 1950, reagents developed for targeted application in flotation increased the use of the process to more ores and minerals.[209] Flotation is commonly used now, including during concentration of antimony, cobalt, copper, gold-silver, iron, lead-zinc, nickel, molybdenum, phosphate ores and platinum group metal.[210,211]

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[209] D. Fuerstenau, “A Century of Developments in the Chemistry of Flotation Processing,” in *Froth Flotation: A Century of Innovation*, eds. Maurice C. Furstenau, Graeme Jameson, and Roe-Hoan Yoon (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2007).

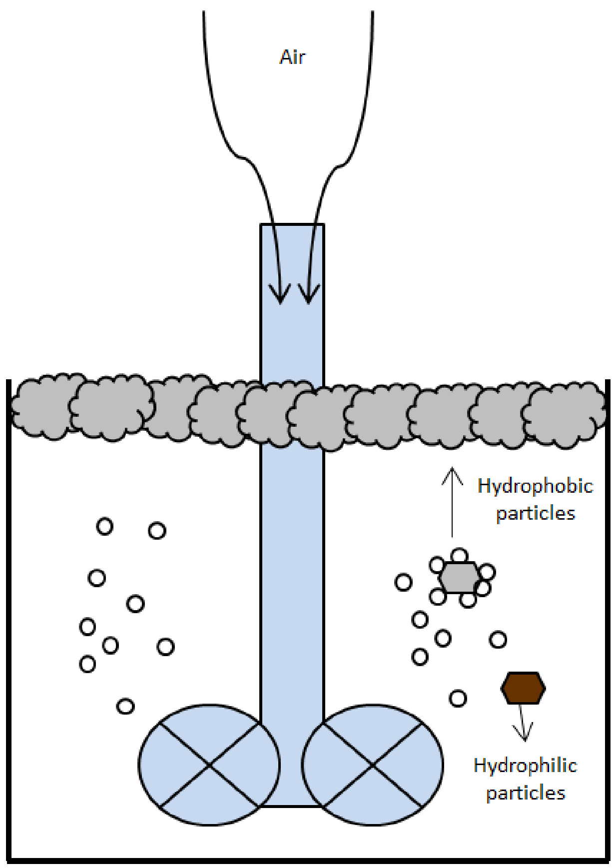
[210] Corby G. Anderson, "The Metallurgy of Antimony," *Chemie Der Erde – Geochemistry* 72 (2012), p. 3-8.

[211] F.K. Crundwell, *Extractive Metallurgy of Nickel, Cobalt and Platinum Group Metals* (Amsterdam: Elsevier, 2011).

Technical Description

Flotation sorts material based on differences in hydrophobicity (water repellency), either inherent or chemically induced. In most cases, the ore must undergo initial processing such as crushing to create distinct grains of valuable mineral and waste material. Ore particles are mixed with water in a slurry, which then goes through flotation cells that agitate the slurry and produce microscopic air bubbles. Chemicals are added that make the desired mineral hydrophobic (water-repelling). As bubbles travel up through the slurry, air attaches to the hydrophobic mineral particles and they float to the top. The concentrated froth layer can then be removed. The hydrophilic (water-loving) waste particles remain in the liquid, where they are transported to the tailings facility.[212] This process is illustrated in Exhibit 1.D.1.

Exhibit 1.D.1. Simplified Flotation Cell[213]



[212] S. Kawatra, "Chapter 14.5: Fundamental Principles of Froth Flotation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2011), Volume 2.

[213] Adapted from S. Kawatra, "Chapter 14.5: Fundamental Principles of Froth Flotation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2011), Volume 2.

Flotation is a versatile process that can separate minerals with a range of particle densities.[214] In addition, a variety of chemical reagents allow flotation to work even with ores that are not naturally hydrophobic.

Flotation processes use six categories of reagents: frothers, collectors, modifiers, flocculants, activators and depressants. Frothers control bubble size and ensure that the froth layer at the top is stable. Collectors control the hydrophobicity of the components, such as an oil that bonds only with the surface of a particular mineral, rendering those particles hydrophobic. The remaining types of reagents help create optimal conditions for selective separation by influencing the way that collectors attach to mineral surfaces – for example, by controlling pH or modifying the way that collectors adhere to specific mineral surfaces.[215] Some commonly used reagents are shown in Exhibit 1.D.2.

Exhibit 1.D.2. Common Reagents Associated with Flotation Processing[216]

FROTHERS	COLLECTORS	DEPRESSANTS	FLOCCULANTS
Aliphatic Alcohol Pine Oil Polyglycol Ether	Xanthates Dithiophosphates Thionocarbamates Cyanide Salt Kerosene	Cyanide Lime	Aluminum Salts Anionic Polyacrylamide

Potential Sources of Hazardous Substances

Flotation processes generate tailings that consist of a mixture of waste material and the remaining liquid, which consists mostly of water and any remaining reagents. These are generally pumped to a tailings impoundment, where solids are settled out of the solution.[217, 218, 219]

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[214] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[215] S. Kawatra, "Chapter 14.5: Fundamental Principles of Froth Flotation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2011), Volume 2.

[216] S. Kawatra, "Chapter 14.5: Fundamental Principles of Froth Flotation," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2011), Volume 2.

[217] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 4: Copper (Washington, DC: U.S. Government Printing Office, 1994).

[218] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 1: Lead-Zinc (Washington, DC: U.S. Government Printing Office, 1994).

[219] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 3: Iron (Washington, DC: U.S. Government Printing Office, 1994).

In some cases, reagents have the potential for environmental harm. Of the reagents shown in Exhibit 1.D.1., some (e.g., pine oil, anionic polyacrylamide) are relatively benign. In contrast, cyanide, certain aluminum salts, certain aliphatic alcohols, glycol ether and lime are CERCLA hazardous substances.[220] Xanthates (often used as collectors for copper, nickel, lead, zinc, silver, and gold) are not listed as CERCLA hazardous substances, but can be toxic to freshwater fish and invertebrates.[221] Xanthates have also been known to have negative effects on soil biota, including the inhibition of nitrogen transformation and nitrite oxidization.[222]

Most of these reagents are consumed during flotation, with only small residual quantities making it into the tailings.[223] Facilities may dispose of wastes from various processes in the same waste management units, however, with the resulting mixture containing more hazardous constituents than tailings from flotation alone.[224]

Proper construction of tailings ponds allows potential contaminants to settle out of water before it discharges. When chemicals are added to the slurry, leak detectors and linings must be employed to ensure that no harmful substances are discharged to the environment.[225,226, 227] The primary method of managing environmental discharges from tailings is to pump the mineral slurries to tailings ponds, where the solids settle to the bottom and consolidate, allowing the cleaned liquid above to be recycled to the plant or discharged. See Section 2.C. for more details on tailings management.

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[220] "EPCRA/CERCLA/CAA Section 112(r) Consolidated List of Lists," U.S. Environmental Protection Agency, updated March 2015. Accessed November 3, 2015, at: http://www2.epa.gov/epcra/epcracerclacaa-ss112r-consolidated-list-lists-march-2015-version; and "CERCLA Substance Priority List," ATSDR, updated 2013. Accessed November 3, 2015 at: http://www.atsdr.cdc.gov/spl/.

[221] M.C. Fuerstenau, *The Toxicity of Selected Sulfhydryl Collectors to Rainbow Trout* (Rapid City, Bureau of Mines Open File Report 11-75 (Rapid City, SD: South Dakota School of Mines & Technology, 1974).

[222] J. Ashworth, G.A. Rodgers, and G.G. Briggs, "Xanthates as inhibitors of fertilizer nitrogen transformation in soil," *Chemistry and Industry* 3 (1979), p. 90-92.

[223] J.R. Hawley, *The Use, Characteristics and Toxicity of Mine-mill Reagents in the Province of Ontario* (Toronto: Ministry of the Environment, 1972).

[224] U.S. Environmental Protection Agency, *Mineral Processing Facilities Placing Mixtures of Exempt and Non-Exempt Wastes in On-site Waste Management Units: Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 2013).

[225] D. Dahlstrom, "Chapter 14.7: Dewatering Methods," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011).

[226] For more details on the construction of tailings ponds in regards to specific site and tailings characteristics, see D. Van Zyl, J. Johnson, "Chapter 8.5: Tailings Disposal Design," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997).

[227] D. Dahlstrom, "Chapter 14.7: Dewatering Methods," in *SME Mining Engineering Handbook*, Third Edition, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011).

State and Federal Regulations

While few regulations pertain specifically to flotation processing and its waste products, the CWA, state groundwater programs, hardrock mining, and solid waste regulatory frameworks address these practices at the state and federal level. Section 2.C.4. describes the regulatory framework for tailings in more detail.

Federal Regulations

Potential releases from flotation processing are regulated under the ELGs outlined by the CWA for many minerals, including gold, silver, copper, lead and titanium.[228] These requirements set discharge limits and water quality requirements for direct discharges to surface water from flotation operations for sediment, metals and pH. Runoff from tailings impoundments may be regulated under stormwater permits.[229] Stormwater permits regulate stormwater contaminated by contact with material from mining activities.

While RCRA does not directly address tailings from flotation processing (a beneficiation waste under the Bevill exclusion), state and local governments implement solid waste management guidelines under RCRA Subtitle D. Specifically, the federal government provides information and policy guidance to support state and local governments, such as criteria for the safe re-use of tailings in other industrial applications.[230] In situations where facilities combine tailings with mineral processing wastes that exhibit hazardous characteristics, the waste mixtures may also fall under RCRA Subtitle C regulations. MSHA also specifies inspections and safety standards for impoundments, retention dams and tailings ponds, and the FEMA is charged with administering a national dam safety program that includes tailings structures.[231]

Mining operations on federal land are subject to additional regulation. According to BLM Section 3809 rules, mining operations must prevent unnecessary or undue degradation, which includes managing all tailings and any other waste produced from mining operations.[232] Tailings from flotation processing fall under this general regulation as waste produced by mining operations and are thus subject to the permitting and approval requirements for operations on BLM lands.

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[228] 40 CFR 436 (mineral mining and processing); 40 CFR 440 (ore mining and dressing).

[229] The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[230] U.S. Environmental Protection Agency, *Final Rule: Criteria for the Safe and Environmentally Protective Use of Granular Mine Tailings Known as "Chat"* Docket EPA-HQ-RCRA-2006-0097 (Washington, DC: U.S. Government Printing Office, 2007).

[231] 30 CFR Part 57, Subpart S. For more information, see: "Dam Safety Standards and Technical Guidance," MSHA. U.S. Department of Labor. Accessed October 30, 2015 at: http://www.msha.gov/DamSafety/DamSafetyTechGuidance.asp.

[232] 43 CFR Part 3809

State Regulations

Several state regulations manage tailings through state environmental programs, state mining regulatory programs, solid waste management programs, or dam safety regulations. For example:

- **Alaska**'s Department of Environmental Conservation Solid Waste Disposal Permit makes tailings from hardrock mines and tailings from placer mines that have been amalgamated or chemically treated subject to the state's solid waste management general standards and requirements, which usually necessitate pre-operation, operation, and post-closure monitoring.[233]
- **Arizona's** Groundwater Permit requires mines in active groundwater management areas to reduce water loss from tailings impoundments.[234] As a result, water removed from tailings is usually recycled back into industrial processes.
- **California** manages mining wastes through the state's Porter-Cologne Water Quality Control Act. All mining units, including tailings structures, must comply with siting and construction standards. Disposal and management regulations for mining waste establish monitoring, closure, and maintenance requirements, which are based on wastes' potential hazard to water.[235]
- **Idaho's** Dam Safety Program regulates tailings structures through dam and impoundment structure requirements. The state oversees the construction, enlargement, alteration, repair, operation, and maintenance of dams and impoundments.[236]
- **Montana**'s Hard Rock Mining Reclamation Act specifies that milling operations are subject to permitting, requiring a detailed description of the design, construction, and operation of the mill, tailings, and waste rock disposal facilities, and best management practices are expected in the disposal of tailings and other waste.[237]

Non-Operating Sites and Currently Operating Facilities

Non-Operating Sites

Eight of the 29 non-operating mining and processing CERCLA sites reviewed used flotation processing techniques.[238] The causes of releases were identified for six of the eight CERCLA

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[233] Title 18 AAC Chapter 60- Solid Waste Management

[234] ARS §45

[235] 27 CCR Div. 7.1

[236] Idaho Code 42-17; IDAPA 37.06.06; IDAPA 37.03.05

[237] ARM 17.24.101-ARM.17.24.189

[238] Cyprus Tohono Mine (EPA ID AZD094524097), Captain Jack Mill (EPA ID COD981551427), Summitville Mine (EPA ID COD983778432), Bunker Hill Mining & Metallurgical Complex (EPA ID IDD048340921), Blackbird Mine (EPA ID IDD980725832), Li Tungsten Corp. (EPA ID NYD986882660), Tar Creek (Ottawa County) (EPA ID OKD980629844), Gilt Edge Mine (EPA ID SDD987673985).

sites that used flotation, although there is no indication that the releases at these sites were directly caused by flotation processing. Some releases were influenced by waste management practices, such as tailings storage facility failures.

The review identified one non-operating, non-CERCLA site that directly released flotation solution, with minimal evidence of long-term environmental impacts. The Jamestown Mine in Tuolomne County, California (MSHA ID 0404695) began gold mining and processing operations in 1986. In 1987, the flotation operations released 500 gallons of flotation solution into the area adjacent to a processing building, with 200 gallons released into a sediment pond. Test samples taken the day of the release indicated that concentrations of the flotation compounds were below detectable levels.[239]

Currently Operating Facilities

At least fifteen of 70 currently operating facilities reviewed use flotation as a method for mineral processing.[240] Copper is mined at five of these sites.[241] At least 13 of the 15 facilities experienced hazardous substance releases, but little evidence was available concerning the causes and types of releases, including whether the release was associated with the flotation process.

The review identified one currently operating facility that directly released flotation solution in violation of the facility's water quality permit. The Robinson Nevada Mining Company operates the Robinson Operation surface mine (MSHA ID 2601916) in White Pine County, Nevada. The facility produces gold and copper using flotation processes. [242] The facility released copper flotation tailings five times in 1996, leading to violations of its water pollution control permit.[243] Releases ranged from 1,500 gallons to 66,000 gallons per release. The largest spill, on February 12, 1996, contaminated 2.3 miles of a downstream drainage bed. This release violated the Nevada Revised Statutes 445A.465 law regarding discharges of injection fluids or pollutants.

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[239] U.S. Environmental Protection Agency, Office of Solid Waste, *Human Health and Environmental Damages from Mining and Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 1995). Accessed December 7, 2015, at: http://www3.epa.gov/epawaste/nonhaz/industrial/special/mining/minedock/damage/damage.pdf.

[240] Asarco Ray (MSHA ID 0200150), Ashdown (MSHA ID 2600578), Coeur Kensington (MSHA ID 5001544), Freeport McMoRan Morenci (MSHA ID 0200024), Hecla Greens Creek (MSHA ID 5001267), Intrepid Potash East/West (MSHA IDs 2900175 (West) and 2900170 (East)), Mosaic South Pasture Hardee (MSHA ID 0800903), Nyrstar East Tennessee Complex-Young (MSHA ID 4000170), Nyrstar Middle Tennessee Complex- Elmwood/Gordonsville (MSHA ID 4000864), Rio Tinto Kennecott Bingham Canyon-Copperton-Magna (MSHA IDs 4200149 and 4201996), Robinson Nevada (MSHA ID 2601916), Stillwater East Boulder (MSHA ID 2401879), Stillwater Stillwater/Columbus (MSHA ID 2401490), Thompson Creek (MSHA ID 1000531), US Silver Galena (MSHA ID 1000082)

[241] Asarco Ray (MSHA ID 0200150), Freeport McMoRan Morenci (MSHA ID 0200024), Rio Tinto Kennecott Bingham Canyon-Copperton-Magna (MSHA IDs 4200149 and 4201996), Robinson Nevada (MSHA ID 2601916), US Silver Galena (MSHA ID 1000082)

[242] "Robinson Mine," KGHM Polska Miedz. Accessed October 27, 2015: http://kghm.com/en/our-business/mining-and-enrichment/robinson.

[243] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

The smaller spills contaminated small areas of soil. Information about long-term environmental effects and regulatory enforcement actions was not readily available.

E. Cyanidation

Introduction

In cyanidation, cyanide is used to separate gold or silver from its ore. This beneficiation process dissolves gold and silver from ore, separating it from waste material (tailings or spent heap). The cyanide solution containing gold and silver is then processed on site by carbon adsorption or by zinc precipitation (Merrill-Crowe process) to produce doré metal, a semi-pure mixture of gold and silver. Cyanidation is typically performed using either agitated tank or heap leaching processes.[244]

Cyanide leaching generates most of the gold produced in the United States and worldwide. Leaching tanks, leach pads, piping, and storage facilities (e.g., process solution ponds, tailings facilities) can release cyanide and other mobilized contaminants into the environment, however, at both active and abandoned mines. Coincident with increased regulatory requirements, mitigation and best management practices have evolved in an effort to control the risk of these releases and better mitigate their impacts.

Nevertheless, substantial releases of cyanide have been observed both historically and as a result of contemporary mining practices, suggesting that technological advances and regulatory oversight may have not eliminated the potential for serious environmental contamination. Limited evidence from the literature and several Superfund sites also suggests that financial health of mining firms may play a role in site operations and the incidence of releases, with volatile metal commodity prices a key determinant of a mining company's bottom line.

Past and Current Use

Cyanidation is the predominant mineral processing method currently in use in the United States to process gold ores, as well as to recover byproduct silver contained in most gold ores.[245]

Agitated tank leaching processes have been in use in the United States since 1891, with heap leaching and carbon adsorption processes emerging in the 1970s.[246] Heap leaching systems are typically used for treatment of low-grade oxidized ores, with their use increasing during periods of high commodity prices. Because of lower capital costs, heap leaching is used when agitated

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[244] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[245] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[246] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

tank leaching processes are not cost effective.[247,248] While used throughout the United States, this process is predominant in Nevada, where ores are more amenable to heap leaching methods.[249]

In 1991, all forms of cyanidation produced 90 percent of the gold produced in the United States. Of that amount, 33 percent was produced by heap leaching and 56 percent was produced by tank leaching.[250] Updated statistics on the current use of cyanidation by the U.S. mining industry are not available.

Technical Description

Two main types of cyanide leaching systems process ore at currently operating facilities: agitated tank leaching, and heap leaching. Preliminary steps to prepare and make the ore more amenable to cyanidation include physical processing (e.g., crushing, grinding, and sizing, described in Section 1.C.), flotation (discussed in Section I.D. of this document), and oxidation (e.g., roasting, described in Section I.G.). During and after leaching, the two most common recovery processes used to remove gold and other metals from the cyanide solution are: 1) carbon adsorption, desorption, and electrowinning; and 2) the Merrill-Crowe method (zinc precipitation). The resulting intermediate product is further refined by smelting, and in most cases the cyanide solution is recycled. These ancillary processes are addressed within the following sections on agitated tank and heap leaching.

Agitated Tank Leach

Exhibit 1.E.1. presents the agitated tank leaching process. The standard agitated tank cyanide leach process consists of crushing and then grinding the ore to roughly the consistency of fine sand. Alternatively, concentrate from flotation processing, which uses chemical reagents and air bubbles to separate minerals of interest, may also be used as feed to the agitated tank cyanide leach process. The ground ore or concentrate is combined with water, sodium cyanide, and quick lime (to maintain the alkalinity of the solution), and passed through a series of agitated mixing tanks with a residence time of 24 hours.[251] Dissolved gold and silver are collected with activated carbon (carbon-in-pulp adsorption or carbon-in-leach processing), thickener tanks, vacuum

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[247] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[248] Dump leaching is a rarely used third type of cyanidation in which uncrushed ore or waste rock is stacked in a pile, sometimes without a liner. This process requires even less capital investment, but requires increased processing time and results in a lower recovery rate. However, some technical descriptions use the terms "heap leaching" and "dump leaching" interchangeably. This document describes and refers to the two main types of cyanidation: agitated tank leaching and heap leaching.

[249] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002). Accessed August 27, 2015, at: http://www.kcareno.com/pdfs/mpd_heap_leach_desn_and_practice_07apr02.pdf.

[250] Carlos D. Da Rosa, James S. Lyon, and Philip M. Hocker, *Golden Dreams, Poisoned Streams: How Reckless Mining Pollutes America's Waters, and How We Can Stop It* (Washington, DC: Mineral Policy Center, 1997).

[251] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

filters, or zinc precipitation.[252] Electrowinning, which uses electric currents to further separate metals, and smelting then produce doré metal, a semi-pure mixture of gold and silver. Mercury, which is commonly present in gold ores, is removed as a byproduct.[253]

Heap Leaching

Exhibit 1.E.2. shows the cyanide heap leaching process. Unprocessed, crushed, or agglomerated (pelletized) ore is placed on a leach pad on an impermeable barrier.[254] Water-based cyanide leach solution is applied to heap leach piles using sprinklers or misters. After passing through the pile of ore and dissolving precious metals, the gold- and silver-containing (pregnant) cyanide solution is collected in a solution pond or in a valley-fill containment. Metal from cyanide heap leaching processes is recovered using activated carbon or, if the ore is high in silver content, by zinc precipitation. The recycled cyanide solution is then reapplied to the ore stack. Similar to agitated tank leaching, electrowinning and smelting then produce doré metal, with mercury removed as a byproduct.[255]

Heaps can be constructed on flat ground (the most common type of heap-leach design), or can be placed in fairly steep-walled valleys with side slopes up to 20 percent.[256] "Such valley-fill heap leach facilities, which store metal-bearing cyanide solution, dam natural valleys and reduce evaporation. Although the best design practice is to minimize pressure and prevent leakage by minimizing the depth and height of the solution, valley-fill designs store solutions at depths creating significant pressure.

Generally, heap leach systems incorporate impermeable liners to maximize metal recovery and prevent leakage into the environment.[257] Almost all gold heap-leach facility designs operate on a zero-discharge basis and include the following components: a low-permeability compacted soil or geosynthetic clay under-layer; a leak detection layer; a plastic or geomembrane liner; a

[252] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[253] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[254] Ores with small particle size must sometimes be prepared before other processes such as smelting or leaching can be conducted. Agglomeration binds together fine-grained materials that can prevent the efficient flow of solution through the leach pile. Commonly, cement, lime, or other binding and neutralizing agents create larger ore particles. This creates pellets, briquettes or nodules which can be more easily refined using other processes.

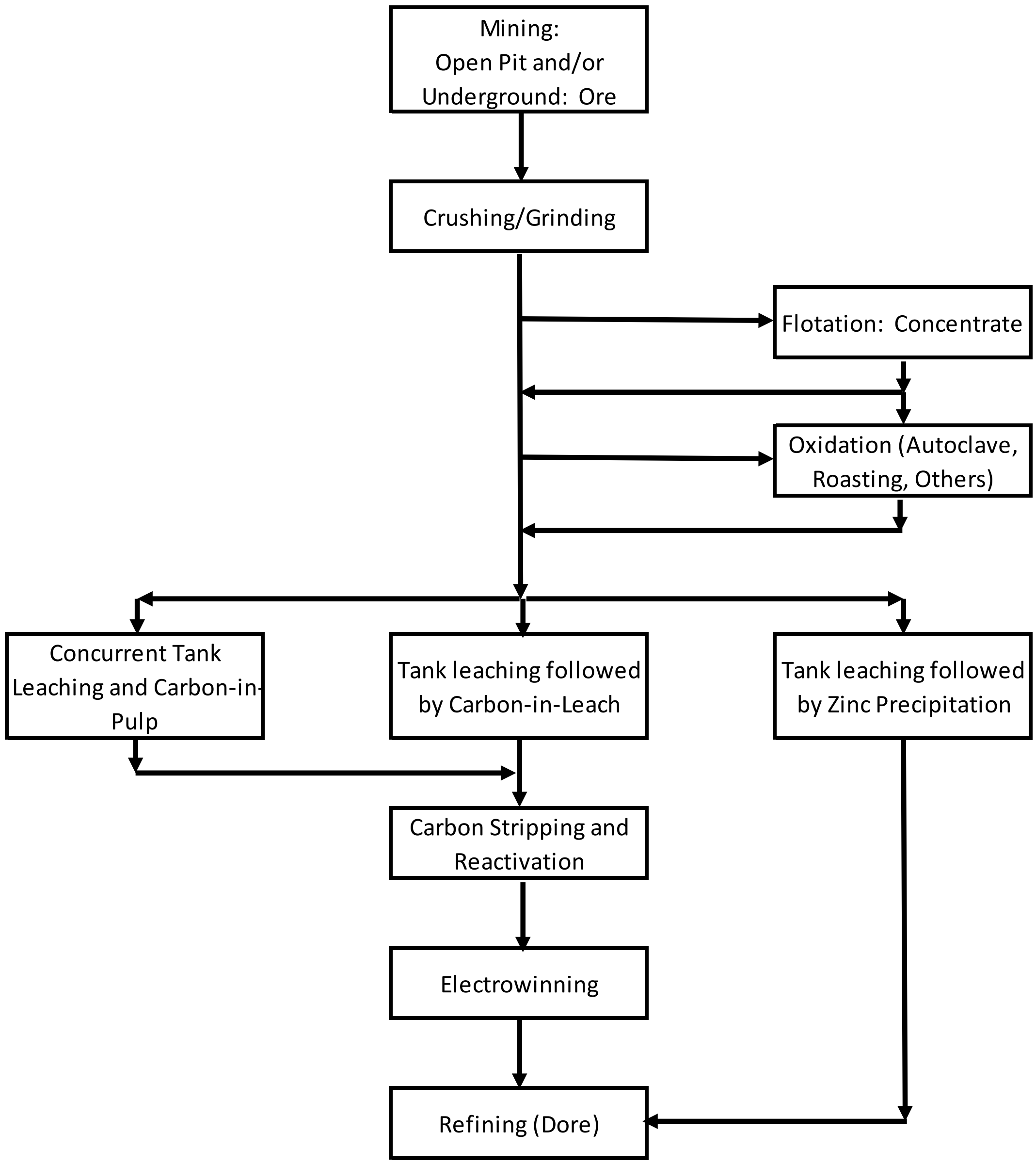
[255] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

[256] John Marsden and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

[257] Donald I. Bleiwas, *Estimated Water Requirements for Gold Heap-Leach Operations*, Open-File Report 2012-1085, Version 1.1 (Washington, DC: U.S. Government Printing Office, 2012). Accessed September 4, 2015, at: http://pubs.usgs.gov/of/2012/1085/pdf/ofr2012-1085_v1-1.pdf

geotextile cover to prevent damage to the plastic liner; drain pipes, and a crushed gravel cover to protect the pipes and liner and provide a permeable base below the heaped ore.[258]

Exhibit 1.E.1. Agitated Tank Cyanide Leaching Processes Flowsheet[259]



[258] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

[259] Adapted from John Marsden and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

Potential Sources of Hazardous Substances

The management of environmental and public safety risks from cyanide use in mining remains a subject of debate in the scientific and engineering communities.[260] In addition to the release of cyanide, discharges from cyanidation processes both during operations and after closure can also contain potentially toxic elements including lead, cadmium, copper, arsenic, and mercury.[261,262]

Because cyanides break down in sunlight, the major environmental impacts occur from the immediate toxicity. In air and surface water, free cyanide typically degrades into non-toxic forms because of volatilization (vaporization), complexation (binding with other substances) and biological degradation.[263] The chemical is much more persistent in groundwater, though. Cyanide toxicity inhibits respiration in fish, birds, and mammals that are exposed via water or air. Accidental releases of cyanide-containing effluent from mining operations, both in the United States and internationally, have resulted in fish kills and other severe shocks to aquatic ecosystems.[264] Humans exposed to high levels of cyanide gas over a short time can experience comas, as well as damage to the brain and heart, sometimes resulting in fatality.

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[260] See, for example: T. Mudder and M. Botz, "Cyanide and society: a critical review," *The European Journal of Mineral Processing and Environmental Protection* 4 (2002), p. 62-74; J.J. Latios, "Cyanide, Mining, and the Environment," *Pace Environmental Law Review* 30 (2013), p. 869-949; R. Eisler and S. Wiemeyer, "Cyanide Hazards to Plants and Animals from Gold Mining and Related Water Issues," *Rev Environ Contam Toxicol* 183 (2004), p. 21-54; and Gavin Hilson and A.J. Monhemius, "Alternatives to cyanide in the gold mining industry: what prospects for the future?," *Journal of Cleaner Production* 14:12-13 (2006), p.1158-1167.

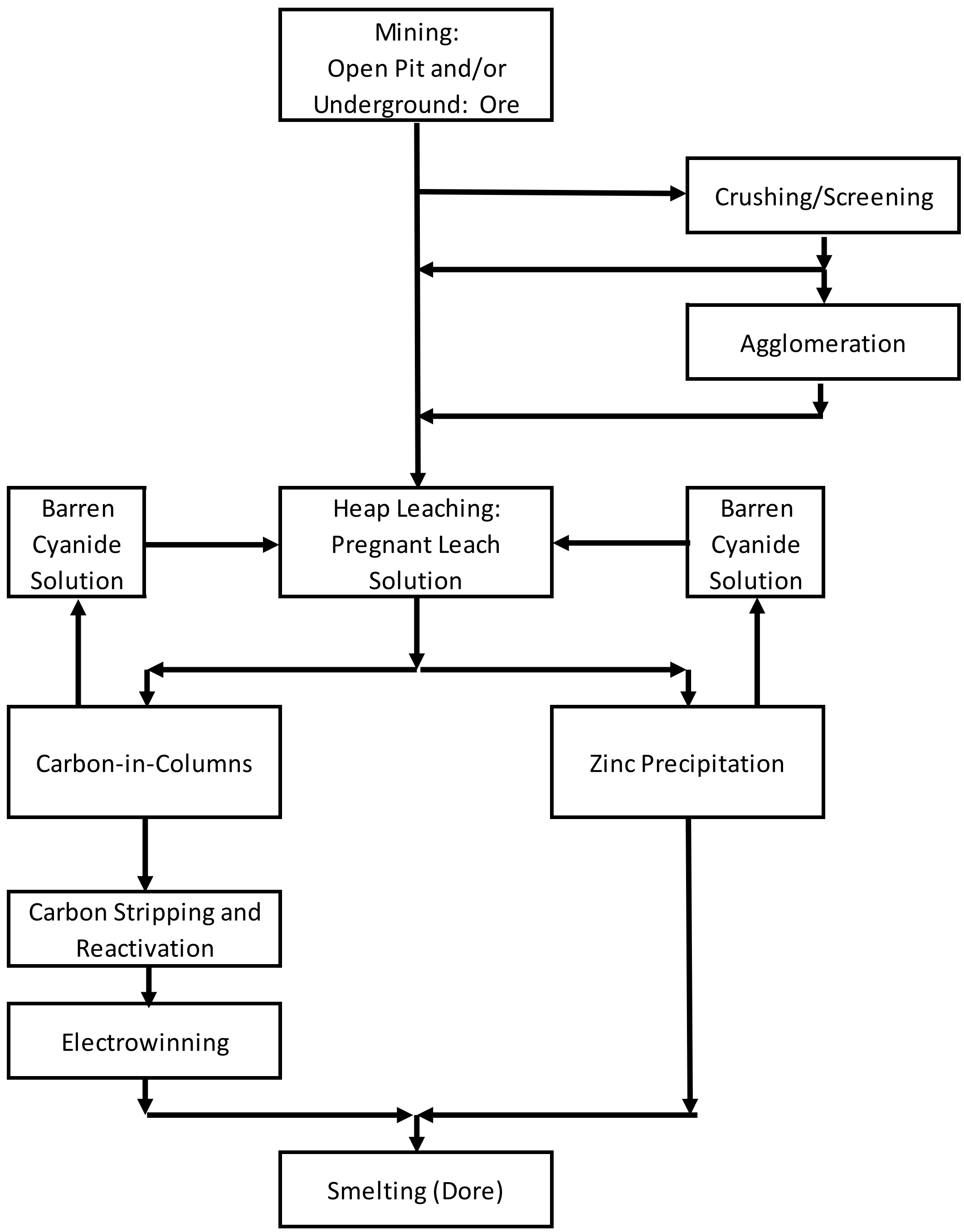
[261] R. Eisler and S. Wiemeyer, "Cyanide Hazards to Plants and Animals from Gold Mining and Related Water Issues," *Rev Environ Contam Toxicol* 183 (2004), p. 21-54.

[262] See The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009); J.L. Jambor, D.W. Blowes, and A.I.M. Ritchie, eds., *Environmental Aspects of Mine Wastes*, Short Couse Handbook, Vol. 31 (Québec: Mineralogical Association of Canada, 2003); K.A., Lapakko, "Regulatory mine waste characterization: A parallel to economic resource evaluation," in *Proceedings of the Western regional Symposium on Mining and Mineral Processing Waters*, ed. F. Doyle (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc.,1990), p. 31-39; and R.W. Lawrence, "Prediction of the behaviour of mining and processing wastes in the environment," in *Proceedings of the Western regional Symposium on Mining and Mineral Processing Waters*, ed. F. Doyle (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc.,1990), p. 115-121.

[263] J.J. Latios, "Cyanide, Mining, and the Environment," *Pace Environmental Law Review* 30 (2013), p. 869-949.

[264] J.J. Latios, "Cyanide, Mining, and the Environment," *Pace Environmental Law Review* 30 (2013), p. 869-949.

Exhibit 1.E.2. Cyanide Heap Leaching Processes Flowsheet[265]



[265] Adapted from John Marsden and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

Cyanide leaching processes create wastes that can present risks of releases of hazardous substances such as cyanide, cyanide-metal complexes, and metals via groundwater and surface water routes. [266] MIW (e.g., acid, alkaline, or neutral mine drainage), runoff originating from exposed heap leach piles or tailings is also a distinct risk associated with this practice (for more information regarding tailings management, see Section 2.C.).[267] Exhibit 1.E.3. discusses these types of potential releases in more detail.

State and Federal Regulations

Current operations are subject to substantially more comprehensive regulatory requirements relative to past operations, where discharges and abandonment were common. At both the federal and state level, land management and environmental regulations address potential environmental risks from gold mining and primary processing, including the practices and potential release risks identified above.

Mining and processing operations may be subject to preliminary environmental planning and assessment, operational requirements and performance standards, and reclamation requirements.

Federal Regulations

Federal agencies have promulgated rules regarding cyanide leaching operations under mining regulations. These include:

- **Solid Waste:** RCRA Subtitle C generally excludes extraction and beneficiation wastes, and many mineral processing wastes, from regulation as hazardous waste. Tailings and mine wastewater containing cyanide are exempt from RCRA Subtitle C under the Bevill Amendment as beneficiation wastes. During the 1998 rulemaking for the RCRA Phase IV Land Disposal Restrictions, EPA confirmed that cyanide-bearing wastes generated from beneficiation processes were not regulated under Subtitle C.[268] Many currently operating gold mines maintain RCRA Subtitle C permits for hazardous wastes unrelated to cyanide.

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[266] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 2: Gold (Washington, DC: U.S. Government Printing Office, 1994).

[267] Mine runoff can result from a number of mining and processing features, including exposed rock tunnels and waste rock tunnels. This issue is not unique to cyanidation practices. Although this process occurs naturally, mining exposes increased quantities of waste rock and tailings to rainwater, snowmelt, and surface water. Acidic drainage reduces the pH levels of surrounding aquatic ecosystems, threatening aquatic life and vegetation, and drainage of any pH level can contain mobilized contaminants.

[268] 63 Federal Register 28556. Vol. 63, No. 100, 28556. May 26, 1998.

Exhibit 1.E.3. Potential Releases Associated with Cyanidation and Ancillary Processes

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Solution from tanks or heap leach piles	Cyanide leaching uses one or combination of the following process chemicals: sodium cyanide, potassium cyanide, sodium hydroxide, nitric acid, and lime, as well as other process chemicals. Process chemicals may be discharged accidentally from drums, tanks and other storage containers during operations and post-closure if not properly disposed. Leaks may also occur from the leaching system itself, such as from heap leach pad liner punctures. Valley-fill heap leach designs create a high risk of solution leakage and storage issues, because of the high fluid pressures associated with tailings dams.[269] Cyanide solution without leached minerals, as well as process water recovered from tailings and heap leach facilities, is recycled back to the agitated tank cyanide leaching process. In addition to cyanide, the leach solutions accumulate metal impurities. Discharges of leach solutions may occur as a result of leakage of ponds, tanks, and piping during operations and may also be responsible for long-term post-closure seepage containing cyanide and metals.[270]	There are a multitude of liner systems and designs that can be applied. The combination of the design and the materials will determine the leakage rate of the liner system.[271] Liner systems can be designed and constructed with leak detection alarm systems and fluid recovery systems. Leak collection systems can be constructed between primary and secondary synthetic liners to collect and remove fluids from leaks, minimizing the pressure on the secondary liner. Fluid collection pipes can transmit fluid away from drainage layers.
Leach tailings	Following cyanidation processing, the spent ore or tailings is discharged to a tailings storage facility (impoundment). These wastes are typically treated to reduce the cyanide concentration, but may contain residual cyanide and cyanide complexes. They may also contain metals present in the ore body.[272] The waste	During mine design, targeted extraction techniques such as selective mining and avoidance could be used to minimize mining of ore resulting in leach tailings that could result in MIW.[273] As part of the leach tailings disposal facility design

[269] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

[270] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

[271] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.1.

[272] Bernd Lottermoser, *Mine Wastes: Characterization, Treatment and Environmental Impacts*, 3rd Edition (Medford, MA: Springer Science and Business Media, 2010).

[273] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	impoundment may be unlined or lined, and in either case might incorporate a collection or pumpback system for recovery of escaped tailings solution. See Section 2.C. for further discussion of tailings management.	engineered barriers such as a liner can be utilized to collect seepage from tailings resulting in reduced seepage management requirements.[274] Another technique is production of paste or dry dewatered leach tailings to reduce potential for MIW.[275] During operations special handling techniques such the addition of alkaline materials or amendments can be used to reduce potential for AMD from leach tailings.[276] At closure leach tailings areas can be reclaimed using dry and wet covers to lessen or minimize discharges of MIW. [277]
Mine drainage	Water percolating through uncovered or otherwise exposed tailings or heap leach piles may react with sulfide minerals, creating acid drainage and other MIW. Depending on the hydrology of the site, the drainage may be discharged to groundwater or surface water. A variety of factors affect the rate of MIW generation from tailings including the water level within the pile, exposure to oxygen, and the presence of bacteria. Tailings and ore piles are susceptible to acid generation because of the increased surface area exposure of minerals not extracted by the cyanide leaching process. Both surface water discharges and seepage to groundwater from tailings impoundments may contain MIW which also increases the leaching and mobility of metals.[278]	In the event the mine drainage requires treatment prior to discharge, either during operations or post-closure, a variety of active, passive and in situ mine drainage treatment techniques are potentially applicable.[282]

[274] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.1.

[275] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.8.

[276] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.4.2.

[277] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2.

[278] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 2: Gold (Washington, DC: U.S. Government Printing Office, 1994).

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	Nevada contains most of the current U.S. gold operations.[279] A 2003 USGS study of hydrological and geological conditions of northern Nevada found that mines in Nevada are much less likely than those in other states to discharge acid waters to local waterways because of low precipitation, the isolated nature of local waterways, composition of ores, and prevalence of soils containing neutralizing lime.[280] Risks from seasonal precipitation still exist, however, and there are several documented instances of AMD contamination from currently operating Nevada gold mines.[281]	
Mercury releases	Gold ore processing and production facilities are the seventh largest source of mercury air emissions in the United States.[283] Mercury commonly occurs in gold-bearing ore and is a relatively volatile element. As such, it can escape to the atmosphere, particularly from thermal processes. Mercury releases can occur as a result of various cyanidation steps.[284,285] They include preliminary roasting and autoclaving, carbon regeneration, electrowinning, mercury distillation and recovery, and doré furnace smelting. Atmospheric mercury	As part of mine design targeted extraction techniques such as selective mining and avoidance could be used to minimize mining of waste rock that could result in mercury releases.[287] Releases can be reduced using a hypochlorite injection system and by improving process and control equipment efficiency.[288]

[282] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.5.

[279] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Document: Acid Mine Drainage Prediction* EPA 530-R-94-036 (Washington, DC: U.S. Government Printing Office, 1994). Accessed August 13, 2015, at: https://www.epa.gov/sites/production/files/2015-09/documents/amd.pdf

[280] J.T. Nash, *Overview of Mine Drainage Geochemistry at Historical Mines, Humboldt River Basin and Adjacent Mining Areas, Nevada*, USGS Bulletin 2210-E (Washington, DC: U.S. Government Printing Office, 2003). Accessed August 13, 2015, at: http://pubs.usgs.gov/bul/b2210-e/B2210E508V6.pdf

[281] Ronald Eisler, *Biogeochemical, Health, and Ecotoxicological Perspectives on Gold and Gold Mining* (Boca Raton: CRC Press, 2010).

[283] "Fact Sheet: Final Rule to Reduce Mercury Emissions from Gold Mine Ore Processing and Production Sources," U.S. Environmental Protection Agency, updated 2010. Accessed February 13, 2015, at http://www.epa.gov/ttn/atw/area/gold_mines_fs_121610.pdf; and EPA. 2010. National Emission Standards for Hazardous Air Pollutants: Gold Mine Ore Processing and Production Area Source Category; and Addition to Source Category List for Standards. 40 CFR Part 63 Subpart EEEEEEE. 76 FR 9450.

[284] Glenn Miller, "Byproduct Mercury Production in Modern Precious Metals Mines in Nevada," presented at EPA Region 8: 2007 Stakeholder Panel for Managing Domestic Stocks of Commodity-Grade Mercury, July 24-25, 2007. Accessed August 13, 2015, at: https://archive.epa.gov/mercury/archive/web/pdf/byproductmercuryproductioninmodernpreciousmetalsminesinnevada.pdf

[285] Greg Jones and Glenn Miller "Mercury and Modern Gold Mining in Nevada," Final Report to EPA Region 9, October 24, 2005. Accessed January 13, 2015, at http://www.chem.unep.ch/mercury/Trade%20information/NRDC-NEVADABYPRODUCTRECOVERYREPORT.pdf.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	emissions can also volatilize from heaps and tailings facilities resulting in a discharge.[286]	
Land application disposal	Cyanide solution is sometimes applied to soil for disposal, in anticipation that exposure to air will neutralize the solution. Land application of spent cyanide solutions during operations, rinsing, and post-closure seepage treatment activities, however, may introduce cyanide into the environment that does not degrade and persists in the long-term.	In theory, cyanide may be attenuated in soils through treatment methods, including precipitation, biodegradation, and oxidation. Cyanide may persist long-term, though, despite these mechanisms.[289]

[287] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1.

[288] "Nevada Voluntary Mercury Reduction Program (VMRP), Questions and Answers," Nevada Division of Environmental Protection, updated May 2005, accessed August 13, 2015, at https://ndep.nv.gov/mercury/docs/voluntar_mercury_q&a05.pdf.

[286] Glenn Miller, "Environmental Technologies in the Mining Industry," presented April 12, 2011. Accessed August 13, 2015, at: http://dels.nationalacademies.org/resources/static-assets/besr/miscellaneous/Miller.pdf

[289] Glenn Miller, "Environmental Technologies in the Mining Industry," presented April 12, 2011.

State and local governments implement solid waste management guidelines under RCRA Subtitle D. EPA's authority under Subtitle D is limited; its primary role is to promulgate sanitary landfill criteria to prevent adverse effects on health or the environment. As of 2013, EPA has not finalized any solid waste management requirements specifically applicable to the disposal of Bevill waste.

- **Discharges to Water:** Under the CWA ELGs for ore mining and dressing, mines and mills extracting and beneficiating gold and silver ores (except for placer deposits) must comply with a zero-discharge requirement for point sources of process wastewater." [290] These requirements also specify effluent limitations for other wastewater from gold mines and mills, including limits on cyanide, sediment, and other trace elements. Where ELGs may not apply, technology-based limits are developed during the facility-specific permitting process. The NPDES program applies to both active and inactive mines, as well as abandoned mines where legally responsible owners or operators of point sources can be identified. Runoff from tailings impoundments, spent ore piles and waste rock piles may be regulated under stormwater permits.[291] Stormwater permits regulate stormwater contaminated by contact with material from mining activities.
- **Surface Management:** BLM 3809 regulations on surface management have several requirements that relate to cyanide. Under BLM's 1990 cyanide management policy, cyanide operations on BLM lands must create a cyanide management plan and comply with design and treatment standards. Cyanide operations are also factored in BLM's bonding and reclamation requirements. BLM conducts quarterly inspections of operations using cyanide. Operators must construct and operate cyanide facilities such that they will not overflow during local 100-year or 24-hour storm events, snowmelt events, and draindown from heaps during power outages. Operators must also exclude access by the general public, wildlife, and livestock to structures containing lethal levels of cyanide. BLM regulations on the design, operation, and monitoring of waste management structures also apply to cyanide-bearing wastes.[292] The surface management regulations also specify engineering requirements and require liners, containment systems, and inspections for process areas, including cyanide leach operations and tailings impoundments or ponds.

  The USFS has not developed specific policies for cyanide management. Cyanide leaching operations are considered under the general review and permitting process, in which plans of operation and permitting incorporate operation-specific practices.

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[290] 40 CFR Volume 50 Subpart J Section 440. In light of recent Supreme Court cases regarding the scope of waters protected under the Clean Water Act, applicability is further clarified in the proposed rulemaking EPA and Army Corps of Engineers at 79 FR 22187, "Definition of 'Waters of the United States' Under the Clean Water Act," accessed at: https://www.federalregister.gov/articles/2014/04/21/2014-07142/definition-of-waters-of-the-united-states-under-the-clean-water-act

[291] The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[292] 43 CFR Subpart 3809.420

- **Air Emissions:** No federal air regulations specifically oversee cyanide in mining operations. The CAA National Emission Standards for Hazardous Air Pollutants (NESHAPs), however, address mercury emissions from gold mine ore processing and production.[293] While mercury amalgamation is rarely used to extract gold from ore at currently operating mines, mercury can naturally occur in gold ore and can be released through thermal processing and refining.

State Regulations

Many states' regulatory requirements do not specifically address cyanide use in mining. In these cases, however, cyanide releases are controlled under other state environmental regulations. Many states have operational, technology, and performance-based standards for general mining waste management and disposal. For example, Nevada water pollution control regulations and California mining waste management regulations each have minimum design criteria and performance standards for the specific management of mining waste. Nevada's regulations apply to both waste rock piles and to disposal sites for processed ores. California's definition of mining waste (to which design and performance standards apply) includes all solid, semisolid, and liquid waste materials from the extraction, beneficiation, and processing of ores and minerals.

States also set surface and groundwater quality standards. Some of these, including Nevada, include limits on cyanide concentrations. Some states also have stormwater regulations directed at mining, which may regulate runoff from waste disposal units carrying cyanide-bearing wastes. In Alaska, stormwater discharges are required to have Alaska Pollutant Discharge Elimination System (APDES) permits, which require grab sampling for cyanide and effluent limitations consistent with the federal CWA. In Nevada, Nevada Stormwater General Permit NVR300000 applies specifically to stormwater discharges from waste rock dumps and overburden piles metals mining activities.

Some state regulations, which also often apply to operations on private land, specify requirements such as treatment criteria, engineering standards, as well as specific review processes for cyanide operations.[294] For example:[295]

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[293] 40 CFR 63, Subpart EEEEEEE *(area sources)*

[294] For survey reviews of state-level regulations, please see: California State Mining and Geology Board, *A Comparison of Regulatory Surface Mining Programs in the Western United States* (Sacramento: California Department of Conservation Resources Agency). Accessed August 13, 2015, at: http://www.consrv.ca.gov/smgb/reports/Documents/SMGB%20IR%202007-04%20FINAL%20with%20%20appendices.pdf; and U.S. Environmental Protection Agency, Office of Solid Waste. *Technical Report: Treatment of Cyanide Heap Leaches and Tailings* (Washington, DC: U.S. Government Printing Office, 1994). Accessed August 13, 2015, at: https://nepis.epa.gov/Exe/ZyNET.exe/2000EF6J.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C91thru94%5CTxt%5C00000012%5C2000EF6J.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.

[295] EPA selected states for review based on the level of overall hardrock mining and mineral processing activity. These states include: Alaska, Arizona, California, Idaho, Minnesota, Montana, Nevada, and Utah.

- **Nevada's** mining regulations specifically oversee cyanide. [296] Nevada water control regulations establish minimum design criteria for tailings impoundments and ponds. Process areas must obtain a permit to ensure compliance with these engineering standards. These rules also specify the treatment of spent ore from leaching operations. Nevada regulations prohibit mining facilities from causing the concentration of weak acid dissociable (WAD) cyanide in groundwater to exceed 0.2 mg/l. Spent ore left on pads or removed from pads must also demonstrate that WAD cyanide levels in effluent are under 0.2 mg/l. Cyanide in surface waters must not exceed a 22 µg/l average over one hour, and a 5.2 µg/l average over 96 hours.

Nevada's Voluntary Mercury Air Emission Reduction Program established mercury emission reduction goals.[297] Nevada also requires additional technological controls for mercury emissions on thermal units at existing and new metal mines. All users of thermal units at existing metal mines must apply for a Mercury Operating Permit to construct before constructing thermal units.[298]

- **Idaho** regulations require permits for cyanide facilities and lay out standards for construction, operation, and closure. Permit applications require environmental and risk management reviews.[299] Idaho regulations also require that before disposal or abandonment of leached ore, concentrations of WAD cyanide or free cyanide and other pollutants in process-contaminated water draining from the leached ore must be reduced to a level set by the permit writer based on disposal method, location, and potential for surface water and groundwater contamination, or have a pH of between 6.5 and 9 (stabilized).[300]
- **Indiana** water quality standards prohibit operations that produce cyanides and cyanogen compounds from draining these substances directly or indirectly into any sewer system or watercourse. Indiana regulations also require water treatment control facilities to submit monthly reports that detail flow measurements and wastewater characteristics to the Indiana Department of Environmental Management (IDEM).[301]
- Two states have enacted legal bans on the use of cyanide in mineral operations: a **Montana** referendum banned open pits that use cyanide leaching in 1998, and the **Wisconsin** legislature banned cyanide for mining and ore processing in 2001.

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[296] NAC 445A. Accessed at: http://www.leg.state.nv.us/nac/nac-445a.html.

[297] In 2003, Nevada produced 82 percent of the gold mined in the United States. The Toxic Release Inventory (TRI) for Nevada indicates that four Nevada mining companies emitted roughly 90 percent of the state's reported mercury air emissions in 2001. For more information, see: "Fact Sheet: Final Rule to Reduce Mercury Emissions from Gold Mine Ore Processing and Production Sources," U.S. Environmental Protection Agency, updated 2010. Accessed February 13, 2015, at http://www.epa.gov/ttn/atw/area/gold_mines_fs_121610.pdf

[298] NAC 445B.3611 – 445B.3689. Accessed at: http://www.leg.state.nv.us/nac/nac-445b.html.

[299] IDAPA 58.01.13. Accessed at: https://adminrules.idaho.gov/rules/2005/58/0101.pdf.

[300] IDAPA 58.91.13. Accessed at: http://adminrules.idaho.gov/rules/2005/58/0101.pdf.

[301] 327 IAC 2. Water Quality Standards. Accessed at: http://www.in.gov/legislative/iac/title327.html.

Non-Operating Sites and Currently Operating Facilities

The available documents showed that cyanide leach processes were used in at least seven of 15 non-operating sites in the sample, and are used in at least five of 16 currently operating facilities in the sample. Additionally, 2013 TRI data indicated that throughout the United States, at least 23 mineral mining facilities handled cyanide compounds.

The combined history of these sites and facilities suggests that releases can occur during operations, as well as post-closure from waste storage facilities. In addition, financial health of companies can influence operational and mitigation practices employed by the operators, which, in turn, may affect the potential for releases.

Non-Operating Sites

Fifteen non-operating CERCLA sites that mined or processed gold or silver were reviewed.[302] These non-operating sites showed contamination from hazardous substances such as trace elements, cyanide, and polychlorinated biphenyls (PCBs); they also discharged MIW. Cyanide was used at seven of the 15 non-operating sites.

Eleven of 15 sites began operations before 1900. It is possible that these sites became contaminated before the promulgation of major environmental laws and regulations that currently govern mining and primary processing. For example, little mineral extraction or processing activity took place at one of the sites in the sample, the Upper Tenmile Creek Mining Area, after the 1930s. Similarly, California Gulch (EPA ID COD980717938) ceased operations before 1980. ROD and RI/FS documents do not, however, discuss regulatory oversight at the time releases occurred.

At the same time, research shows that since the promulgation of major environmental laws since 1980, gold mines and mineral processing sites using cyanide leach methods have continued to experience releases resulting in CERCLA site listing. In particular, heap leach processes have been associated with five of the six cyanidation-related releases since 1980, while one site experienced leaks from a tank leaching operation. For example, the Brewer Gold Mine used heap leach cyanidation methods to process ore. In 1990, large rainstorms caused a dam to break and over 10 million gallons of the solution spilled into the nearby waterways. The leaked solution killed fish in Little Fork Creek and Lynches River for nearly 50 miles downstream.

The review of these 15 non-operating sites also showed that financial and economic factors appear to have played a role in some of the actions leading up to these CERCLA listings. For example:

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[302] The sample includes: Asarco, Inc. (Globe Plant) (EPA ID COD007063530), Barite Hill/Nevada Goldfields (EPA ID SCN000407714), Blackbird Mine (EPA ID IDD980725832), Brewer Gold Mine (EPA ID SCD987577913), Bueno Mill & Mine Site (EPA ID CON000802129), Bunker Hill Mining & Metallurgical Complex (EPA ID IDD048340921), California Gulch (EPA ID COD980717938), Captain Jack Mill (EPA ID COD981551427), Cimarron Mining Corp. (EPA ID NMD980749378), East Helena Site (EPA ID MTD006230346), Gilt Edge Mine (EPA ID SDD987673985), Pioneer Pit and Gardner's Point Placer Mines (EPA ID CAN000905978), Silver Mountain Mine (EPA ID WAD980722789), Summitville Mine (EPA ID COD983778432), and Upper Tenmile Creek Mining Area (EPA ID MTSFN7578012).

- The Gilt Edge Mine's operations began at the site in 1876, although cyanidation was not used throughout the entire duration of operation. Currently, the 360-acre primary mine disturbance area encompasses a former open pit and a cyanide heap-leach gold mine, as well as prior mine exploration areas used by various companies. The Brohm Mining Company, the most recent mine operator, faced financial problems in the 1990s and informed state authorities that it would not continue site controls. The Brohm Mining Company left 150 million gallons of acidic metal-laden water in three open pits, as well as millions of cubic yards of acid-generating waste rock that requires cleanup and long-term treatment. Elevated nitrates and cyanide were present in heap leach residues. Consequently, EPA proposed a CERCLA listing on May 11, 2000.
- At the Summitville site, Summitville Consolidated Mining Corp., Inc. used cyanide heap leaching to extract precious metals. In 1986, a leak was detected in the heap leach pad. Summitville Consolidated abandoned the site and filed for bankruptcy in December 1992. EPA assumed responsibility of the site as an emergency response and placed the site on the NPL two years later.
- Other non-operating, non-Superfund sites also offer examples of cyanide leaching releases. Zortman and Landusky Mines (MSHA ID 240150) and Beal Mountain Mine (MSHA ID 2401642), all in Montana, used cyanidation to extract precious metals. Both underwent bankruptcy and left significant pollution at their respective sites. In addition to a heap leach pad leak, the Zortman and Landusky facility experienced cyanide releases from a leach pad pipe, a solution pond liner leak, and a process pond liner leak.[303]

Currently Operating Facilities

All 16 currently operating facilities selected for closer analysis have been in operation for fewer than 40 years.[304] Of these, 11 began activities under their current operator after 2000. Equipment failure or operator errors were cited as reasons for almost all documented releases at facilities in the currently operating sample. ERNS and enforcement information revealed evidence of releases of cyanide at three facilities. Our review revealed evidence of 13 cyanide releases from four sites, from 1991-2014. Six of these releases occurred in 2000 or later. Three incident reports in ERNS for the sample of currently operating facilities report spills of cyanide of 22,000

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[303] U.S. Bureau of Land Management, *Final Engineering Evaluation/Cost Analysis (EE/CA) For Water Management at the Zortman and Landusky Mines, Phillips County Montana*, prepared by Spectrum Engineering (Washington, DC: U.S. Government Printing Office, 2006). Accessed August 28, 2015: http://www.blm.gov/style/medialib/blm/mt/field_offices/lewistown/zortman.Par.62509.File.dat/finaleeac.pdf; and US Department of Agriculture. *Final (Revision 6) Engineering Evaluation/Cost Analysis. Beal Mountain Mine. Beaverhead-Deerlodge National Forest Silver Bow County, Montana*, prepared by Tetra Tech (Washington, DC: U.S. Government Printing Office, 2010). Accessed August 28, 2015, at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5183264.pdf.

[304] These include: Apache Mining Old Wasp Mine(MSHA ID: 0203246), Barrick Cortez (MSHA IDs 2600827 and 2602573), Barrick Goldstrike Mine/Mill/Roaster (MSHA IDs 2601089, 2602674, and 2602673), Golden Sunlight Mine (MSHA ID 2401417), Coeur Kensington (MSHA ID 5001544), Coeur Rochester (MSHA ID 2601941), Florida Canyon Mine (MSHA ID 2601947), Geo Nevada Spring Valley (MSHA ID 2602470), Hecla Greens Creek (MSHA ID 5001267), Kinross Crown Resources Buckhorn Mine (MSHA ID 4503615), Newmont Chukar (MSHA ID 2602481), Newmont Emigrant/Mill 6 (MSHA IDs 2602697 and 2602678), Sixteen To One Mine (MSHA ID 0401299), US Silver Galena (MSHA ID 1000082), Veris Gold Saval 4- Jerritt Canyon (MSHA IDs 2602742 and 2601621), and Waterton Global Hollister Mine (MSHA ID 2602535).

gallons, 53,000 gallons, and 159,000 gallons in single incidents, respectively. Permit documents for one currently operating facility also reported an estimated leak of 170,000 gallons of tailings seepage solution from a ruptured underground pipe. Currently operating facilities that experienced releases from cyanidation operations include:

- ERNS data showed reports of 31 releases from 1990-2013 at Barrick Goldstrike Mine (EPA ID NVD000626531), a gold surface mine, including releases of arsenic, mercury, cyanide, and sulfuric acid. Several of these releases involved relatively large quantities, such as a spill of 21,625 gallons of sodium cyanide in 1995 due to equipment failure of a process unit and a spill of 159,000 gallons of cyanide in 2003 due to equipment failure from a tailings impoundment, which affected a nearby dry stream bed. In 2015, Barrick paid penalties for RCRA Subtitle C allegations regarding mercury releases dating back to 2007.[305] The mine has also faced administrative enforcement actions under the Clean Air Act and CERCLA for a release of 3,300 pounds of anhydrous ammonia in 2011, which resulted in the evacuation and transport to local hospitals of 13 workers.[306]
- The **Florida Canyon** mine (MSHA ID 2601947) began operations in Nevada In 1986 as a cyanide heap leach facility. The west side of the mine's leach pad seeped cyanide, mercury, nitrate, and process solution into the groundwater. Remediation began in 2000, but the contamination continued. As a result, the Nevada Department of Environmental Protection issued a Finding of Alleged Violation and Order in August 2012, and BLM placed the mine in noncompliance at the same time. The facility submitted a corrective action plan in 2013, involving a groundwater plume pump back system and capture zone evaluation.[307]

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[305] "Enforcement and Compliance History Online (ECHO): Barrick Goldstrike Mines, Inc. (FRS ID 11003802178)," U.S. Environmental Protection Agency. Accessed September 28, 2016, at: https://echo.epa.gov/enforcement-case-report?id=09-2012-5124.

[306] "Enforcement and Compliance History Online (ECHO): Barrick Goldstrike Mines, Inc. (FRS ID 11003802178)," U.S. Environmental Protection Agency. Accessed September 28, 2016, at: https://echo.epa.gov/enforcement-case-report?id=09-2014-3501.

[307] Office of Resource Conservation and Recover. "Discharges from Hardrock Mines and Mineral Processors Operating in the Modern Mining Era (1978-Present)." September 29, 2016.

F. Acid Leach, Solvent Extraction and Electrowinning

Introduction

Acid leaching (including heap leaching and dump leaching techniques) usually entails treating crushed or uncrushed (run-of-mine) ore with sulfuric acid solution to dissolve the metal, which is then recovered and purified by solvent extraction and electrowinning (SX/EW). Hydrometallurgical processes, including acid leaching, are most commonly applied to oxide ores and low-grade oxide and sulfide mine wastes.[308]Although it is occasionally used for other metals such as nickel and mercury, acid leaching is generally identified with the production of copper, which is by far its most common use.[309] As such, this chapter focuses on acid leach in relation to copper production. Heap and vat leaching processes using cyanide solutions to produce precious metals such as gold and silver are described in Section 1.E.

Leaching tanks, leach pads, piping and storage facilities (e.g., process solution ponds and facilities associated with leaching) can release sulfuric acid and mobilized contaminants into the environment. These leaching solutions can pose significant environmental and human health risks if they are not contained successfully. Information on documented releases reveals that acid leach operations have caused contamination of both surface and groundwaters in addition to injuring habitat and wildlife. Releases due to equipment failures, chronic seepage, or weather-related overflows seem to be the most common problems; acid leach operations need to ensure proper reclamation of spent dump or heap leach piles, maintenance of equipment, and preparation of systems for severe weather in order to minimize environmental impacts.

Past and Current use

Dump leaching involves the application of leach solution to uncrushed and otherwise unprocessed ore, directly from the mine. Because of its low cost, dump leaching is the most common leach method used for production of copper. Dump leaching is also used for nickel mining. Because the dump leaching process can take up to two years to process a given ore pile and in some cases results in relatively low extraction rates, heap leaching may be employed instead. In heap leaching, the operator first crushes or agglomerates the ore, exposing more surface area and making the leach solution more effective. Although also typically used for treatment of low-grade ores, heap leaching is slightly more expensive. Because of this cost

[308] U.S. Congress, Office of Technology Assessment, "Chapter 6: Copper Production Technology," in *Copper: Technology and Competitiveness* (Washington, DC: U.S. Government Printing Office, 1988).

[309] Randolph Scheffel, "Copper Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

differential, the prevalence of heap leaching increases during periods of high commodity prices.[310]

In 1963, General Mills' production of LIX 63 (a copper reagent) led to the widespread use of the SX/EW process for copper production. The SX/EW process has also been extended to the production of nickel, cobalt, and rare-earth elements in some instances, but copper production remains by far the most common use.[311] As of 2013, 38 percent of total U.S. mine production of copper was processed using leaching and SX/EW.[312]

Technical Description

Leaching

Leaching dissolves metals from ore using aqueous or other liquid medium. Two main types of acid leaching systems process ore in contemporary copper mining operations: dump leaching and heap leaching. Raffinate (sulfuric acid solution) is the most common process solution employed during acid leach.

Heap leaching (described in greater detail in Section 1.E.) involves placing ore on a leach pad on an impermeable barrier and applying solution to the ore stack (usually through sprinklers or drip irrigation). Dump leaching is very similar to heap leaching, except ore is not crushed before being placed on the leach pad, and in most cases the leach pad is not lined. Instead, downstream surface and groundwater collections systems are typically employed to capture the leach solution. After leaching, the pregnant solution containing the dissolved metals is piped to the SX/EW plant, and the spent leach solutions are generally recycled for reuse.

SX/EW

In a typical solvent extraction circuit, the pregnant solution from leaching is pumped to a mixer, where the aqueous solution is mixed with an extractant (usually an organic solvent) to form a concentrated metal-laden solution. The extractant is designed to extract only the desired metal (e.g., copper), leaving impurities (such as unwanted metals) in the leachate. The solution is then pumped to a settling tank, where the copper-loaded organic solution is separated from the aqueous leachate solution. The leachate (now devoid of the desired metal) is recycled back to the leaching unit, and the copper-laden solution moves to the electrowinning stage.

In electrowinning, an electric current is passed through the metal-laden solution within an electrolytic cell, which causes the dissolved metals to deposit on cathodes. These purified metal

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[310] John Marsden, and Iain House, *The Chemistry of Gold Extraction*, Second Edition (Englewood, CO: Society for Mining, Metallurgy and Exploration, 2006).

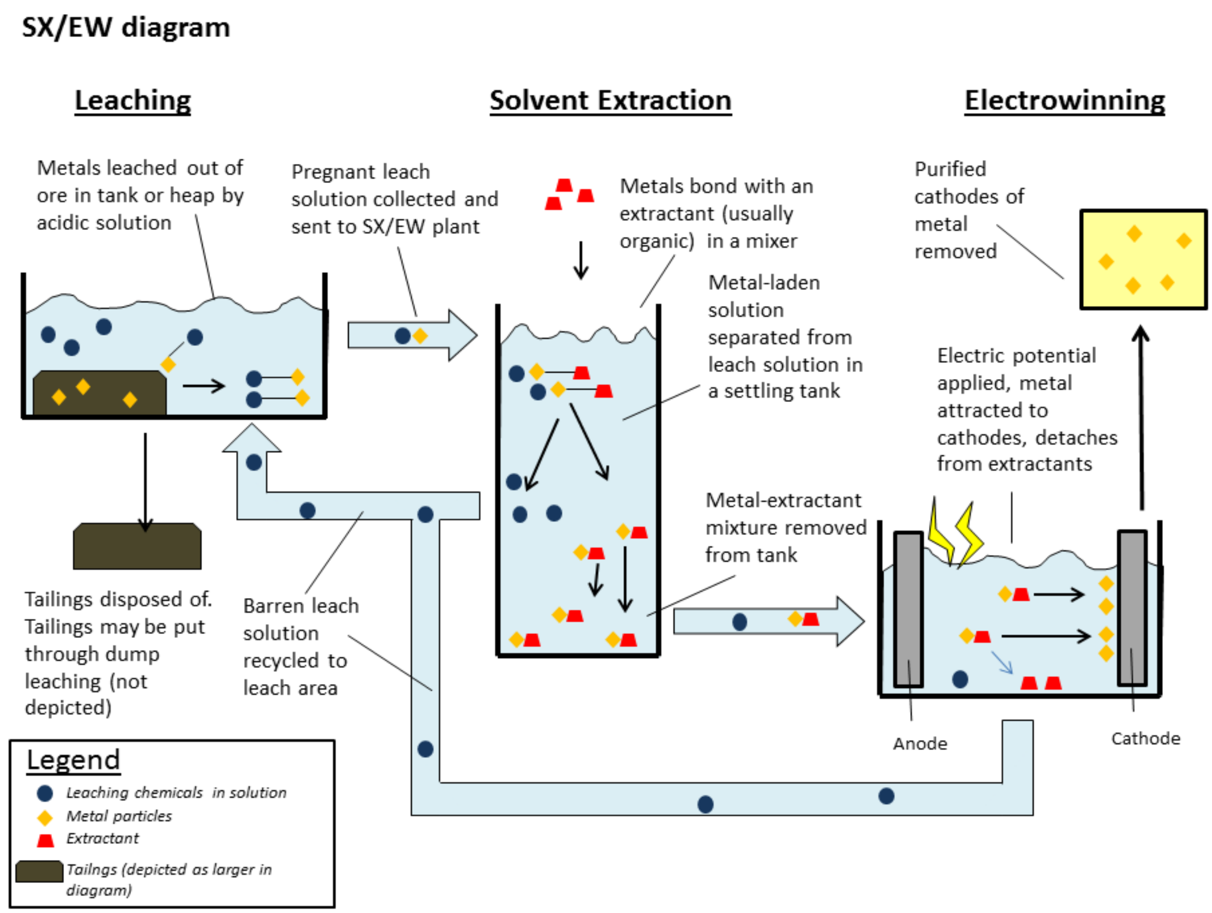
[311] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[312] "USGS Minerals Yearbook: Copper," U.S. Geological Survey, 2013. Accessed Dec. 18, 2015, at http://minerals.usgs.gov/minerals/pubs/commodity/copper/myb1-2013-coppe.pdf.

deposits are ready to be removed, and the remaining solution can be recycled back to the extraction stage.[313]

Exhibit 1.F.1. shows a simplified flow chart of the acid leach, solvent extraction, and electrowinning process.

Exhibit 1.F.1. Acid Leach, Solvent Extraction and Electrowinning Flow Chart



Potential Sources of Hazardous Substances

Sulfuric acid is the most common leaching agent used for acid leach and SX/EW. The process also uses large quantities of organic solvents that can require costly disposal. These process reagents can have serious human health consequences as well as ecological effects.[314] In addition, sulfuric acid can leach metals from other mining wastes and containment areas,

[313] U.S. Congress, Office of Technology Assessment, "Chapter 6: Copper Production Technology," in *Copper: Technology and Competitiveness* (Washington, DC: U.S. Government Printing Office, 1988).

[314] Agency for Toxic Substances and Disease Registry: Division of Toxicology, *Public Health Statement Sulfur Trioxide and Sulfuric Acid* CAS#: 7664-93-9 (Washington, DC: U.S. Government Printing Office, 1998). Accessed December 18, 2015, at http://www.atsdr.cdc.gov/ToxProfiles/tp117-c1-b.pdf.

transporting other contaminants to surface and groundwater systems. While leaching solutions are generally recycled back to the process, failure to contain them properly can result in releases. After leaching has been discontinued, the abandoned leach site can be a source of acidic effluents, hazardous trace elements, and total dissolved solids if it is not properly monitored and managed.[315] MIW and runoff originating from exposed heap leach piles or tailings are also distinct risks associated with this practice.[316] Exhibit 1.F.2 discusses these types of potential releases in more detail.

State and Federal Regulations

Current operations are subject to substantially more comprehensive regulatory requirements relative to past operations, where discharges and abandonment were common. At both the federal and state level, land management and environmental regulations address potential environmental risks from copper mining and primary processing, including the practices and potential release risks identified above.

Mining and processing operations may be subject to preliminary environmental planning and assessment, operational requirements and performance standards, and reclamation requirements.

Federal Regulations

Federal agencies have promulgated rules regarding acid leaching operations under mining regulations. These include:

- **Solid waste.** RCRA Section 3001(b)(1) (the Bevill Amendment) exempts solid waste from extraction and beneficiation, including leaching, solvent extraction, and electrowinning, from regulation as hazardous waste under RCRA Subtitle C. State and local governments implement solid waste management guidelines under RCRA Subtitle D. EPA's authority under Subtitle D is limited; its primary role is to promulgate sanitary landfill criteria to prevent adverse effects on health or the environment. As of 2013, EPA has not finalized any solid waste management requirements specifically applicable to the disposal of Bevill waste.[317]

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[315] U.S. Congress, Office of Technology Assessment, "Chapter 8, Environmental Aspects of Copper Production," in *Copper: Technology and Competitiveness* (Washington, DC: U.S. Government Printing Office, 1988).

[316] Mine runoff can result from a number of mining and processing features, including exposed rock tunnels and waste rock tunnels. This issue is not unique to cyanidation practices. Although this process occurs naturally, mining exposes increased quantities of waste rock and tailings to rainwater, snowmelt, and surface water. Acidic drainage reduces the pH levels of surrounding aquatic ecosystems, threatening aquatic life and vegetation, and drainage of any pH level can contain mobilized contaminants.

[317] L. Luther, "Background on and Implementation of the Bevill Bentsen Exclusions in the Resource Conservation and Recovery Act: EPA Authorities to Regulate 'Special Wastes,'" *Congressional Research Service* R43149 (Washington, DC: U.S. Government Printing Office, 2013).

Exhibit 1.F.2. Potential Releases Associated with Acid Leach and SX/EX

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Solution from tanks or leach piles	Process chemicals such as sulfuric acid that are used in acid leach and SX/EW may be discharged from drums, tanks and other storage containers during operations and post-closure if not properly disposed. Leaks may also occur from the leaching system itself, such as from heap leach pad liner punctures. Valley-fill heap leach designs create a high risk of solution leakage and storage issues because of the high fluid pressures.[318] Discharges of leach solutions may occur as a result of leakage of ponds, tanks, and piping during operations and may also be responsible for long-term post-closure seepage containing acidic effluents and toxic metals.[319,320]	Liner systems can be designed and constructed with leak detection alarm systems and fluid recovery systems. Typically, a minimum of one synthetic membrane is used in combination with a compacted earthen liner. Additional measures, such as using two synthetic liners, can be applied when significant pressure creates cause for concern. Leak collection systems can be constructed between primary and secondary synthetic liners to collect and remove fluids from leaks, minimizing the pressure on the secondary liner. Fluid collection pipes can transmit fluid away from drainage layers. Detailed hydrologic characterization of heap and dump sites before construction and ongoing monitoring are additional proactive management steps that mitigate the possibility of a harmful release.
Leach tailings	Following acid leach operations, the spent ore or tailings is discharged to a tailings storage facility (impoundment). These wastes may be highly acidic and may also contain metals present in the ore body.[321] The waste impoundment may be	During mine design, targeted extraction techniques such as selective mining and avoidance could be used to minimize mining of ore resulting in leach tailings that could result in MIW.[322]

[318] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

[319] Daniel Kappes, "Precious Metal Heap Leach Design and Practice," in *Mineral Processing Plant Design, Practice, and Control Proceedings*, ed. Andrew L. Mular (Englewood, CO: Society for Mining, Metallurgy, and Exploration, 2002).

[320] U.S. Congress, Office of Technology Assessment, "Chapter 8, Environmental Aspects of Copper Production," in *Copper: Technology and Competitiveness* (Washington, DC: U.S. Government Printing Office, 1988).

[321] Bernd Lottermoser, *Mine Wastes: Characterization, Treatment and Environmental Impacts*, 3rd Edition (Medford, MA: Springer Science and Business Media, 2010).

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	unlined or lined, and in either case might incorporate a collection or pumpback system for recovery of escaped tailings solution.	As part of the leach tailings disposal facility design, engineered barriers such as a liner can be utilized to collect seepage from tailings resulting in reduced seepage management requirements.[323] Another technique is production of paste or dry dewatered leach tailings to reduce potential for MIW.[324] During operations special handling techniques such as the addition of alkaline materials or amendments can be used to reduce potential for AMD from leach tailings.[325] At closure leach tailings areas can be reclaimed using dry and wet covers to lessen or minimize discharges of MIW.[326]
Mine drainage	Water percolating through uncovered or otherwise exposed tailings or leach piles may react with sulfide compounds, creating acid drainage. Depending on the hydrology of the site, the acid drainage may be discharged to groundwater or surface water. A variety of factors affect the rate of acid drainage generation from tailings, including the water level within the pile, exposure to oxygen, and the presence of bacteria. Tailings and ore piles are susceptible to acid generation because of the	In the event the mine drainage requires treatment prior to discharge, either during operations or post-closure, a variety of active, passive and in situ mine drainage treatment techniques are potentially applicable.[328]

[322] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1.

[323] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.1.

[324] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.8.

[325] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.4.2.

[326] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	increased surface area exposure of minerals not extracted by the leaching process. Both surface water discharges and seepage from tailings impoundments may contain acid drainage which also increases the leaching and mobility of metals.[327]	

[328] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.5.

[327] U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 2: Gold (Washington, DC: U.S. Government Printing Office, 1994).

Facilities sometimes dispose of Bevill-exempt wastes in the same waste management units as non-exempt hazardous wastes.[329] In situations where facilities combine tailings with other wastes that exhibit hazardous characteristics, the waste mixtures may fall under RCRA Subtitle C regulations.

- **Discharges to Water:** Untreated tailings may not be discharged into surface waters.[330] To comply with water quality standards under the CWA, mine operators must obtain permits under NPDES for any discharge of pollutant from a point source to waters of the United States.[331] For many hardrock commodities, EPA has promulgated ELGs requiring technology-based controls and establishing specific water quality standards. For example, the ore mining and dressing ELG establishes a zero-discharge requirement for point sources of process wastewater for copper mining and milling operations using leaching processes, and the nonferrous metals manufacturing ELG establishes water quality requirements for discharges from electrowinning operations.[332] For discharges or pollutants not covered by the ELGs, EPA or the delegated state authority incorporates limits into permits on a site-specific basis. Under the CWA ELGs for ore mining and dressing, mines and mills extracting and beneficiating copper ores using leaching processes must comply with a zero-discharge requirement for point sources of process wastewater."[333] Where ELGs may not apply, technology-based limits are developed during the facility-specific permitting process. The NPDES program applies to both active and inactive mines, as well as abandoned mines where legally responsible owners or operators of point sources can be identified.

  Runoff from tailings impoundments, spent ore piles, and waste rock piles may be regulated under NPDES stormwater permits if it is not commingled with process water or

[329] An EPA survey of 106 facilities in 1989 indicated that 20 facilities placed mixtures of Bevill-exempt and non-exempt wastes in the same waste management unit. See: U.S. Environmental Protection Agency, *Mineral Processing Facilities Placing Mixtures of Exempt and Non-Exempt Wastes in On-site Waste Management Units: Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 2013).

[330] U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003).

[331] Point sources are defined broadly, includes any discernable, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, or container. "Waters of the United States" includes navigable waters, tributaries, interstate waters, intrastate waters used by interstate travelers, or for industrial purposes by industries engaged in interstate commerce. Generally, mining operations would fall under the Clean Water Act for process wastewater, mine drainage, and stormwater. See: U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003).

[332] 40 CFR 440 (ore mining and dressing); 40 CFR Part 421 (nonferrous metals manufacturing).

[333] 40 CFR Volume 50 Subpart J Section 440. In light of recent Supreme Court cases regarding the scope of waters protected under the Clean Water Act, applicability is further clarified in the proposed rulemaking EPA and Army Corps of Engineers, "Definition of 'Waters of the United States' Under the Clean Water Act," 79 *FR* 22187 (Washington, DC: U.S. Government Printing Office, 2014). Accessed December 18, 2015, at: https://www.federalregister.gov/articles/2014/04/21/2014-07142/definition-of-waters-of-the-united-states-under-the-clean-water-act

mine drainage.[334] Stormwater permits regulate stormwater contaminated by contact with material from mining activities, primarily requiring site-specific pollution prevention planning and/or implementation of mitigation practices.[335] These include treatment requirements, operating procedures, practices to control runoff, and monitoring.

- **Surface Management:** Mining operations on public federal land are subject to additional regulation. According to the BLM Section 3809 rules, mining operations must prevent unnecessary or undue degradation, which includes managing all tailings, rock dumps, deleterious material or substances and any other waste produced from mining operations.[336] Any field-scale testing using sulfuric acid (e.g., test heaps) must be conducted under a formal plan of operations, which includes environmental evaluation. BLM guidance indicates that proper disposal of mining wastes must involve siting of tailings facilities to minimize potential for environmental impact. Further, operators must conduct reclamation to maximize long-term geotechnical and geochemical stability and minimize the formation and release of leachate.[337] Requirements include:
    - Operators must have low-permeability liners or containment systems to minimize the release of solution to the environment using best available technology, and must monitor for potential contaminant releases from leaching operations and tailings impoundments.
    - Operators must construct a secondary containment system around vats, tanks, and recovery circuits that can retain solution from a leak or failure, in order to prevent the release of toxic solutions to the environment.
    - Operators must design, construct, and operate leaching facilities and tailings impoundments to contain precipitation from the local 100-year, 24-hour storm event.
- **Air Emissions:** Leaching and the SX/EW process do not produce the air pollution associated with alternative processes, such as smelting. No regulations under the CAA or other laws directly apply to acid leaching, solvent extraction, and electrowinning.

State Regulations

Many states have operational, technology, and performance-based standards for general mining waste management and disposal in state solid waste regulations, state groundwater pollution laws, dam safety programs, or state mining laws. Generally, state and local governments

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[334] Seepage to groundwater is not considered a point source, and is not regulated under the Clean Water Act. The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[335] Best management practices for stormwater permits are described at 40 CFR 122.2.

[336] 43 CFR Part 3809

[337] U.S. Department of the Interior, Bureau of Land Management, *Surface Management Handbook* H-3809-1 (Washington, DC: U.S. Government Printing Office, 2012), Section 5.3.2

implement solid waste management guidelines under RCRA Subtitle D, establishing operating and closure requirements that apply to all types of industrial waste disposal units. States with delegated authority also implement CWA regulations, with state programs at least as stringent as federal regulations. Several state regulations specifically manage mine tailings, although in some cases tailings with no chemical additives are excluded from regulation. For example:

- **Alaska's** land reclamation performance standards require heap leach operations to neutralize spent ore (AS 27.19.020; 11 AAC 97.200-240).
- **Arizona's** APP program requires leaching operations and tailings facilities to use best demonstrated control technology and to comply with Aquifer Water Quality Standards.
- **Idaho's** Rules for Ore Processing require pollutant levels in water draining from leached ore to be reduced to a level established in a permit, and to have a pH of between 6.5 and 9 (IDAPA 58.91.13).

Additional examples of specific state programs for tailings management are discussed in Section 2.C.

Non-Operating Sites and Currently Operating Facilities

The available documents identified acid leach and/or SX/EW processes as a practice for at least two of 29 non-operating sites in the sample,[338] and at least 9 of 70 currently operating facilities in the sample.[339] Copper was the most common commodity produced at these sites.

The combined history of these sites and facilities suggests that releases associated with acid leach and SX/EW processes can occur during operations, as well as during the post-closure period from waste storage facilities.

Non-Operating Sites

Out of the two non-operating sites in the sample that identified acid leach and SX/EW as a process, one site presented evidence of related contamination:

- The **Cyprus Tohono** (EPA ID AZD094524097) mine is located near Casa Grande, Arizona. Between 1975 and 1983, this site leached oxide ore using sulfuric acid solution (raffinate) and then used SX/EW to produce copper cathodes. The leach tailings were excavated and hauled to nearby storage areas. Soil in the storage areas was later found to have elevated levels of selenium, sulfate, and other trace elements and nearby

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[338] Cyprus Tohono Mine (EPA ID AZD094524097) and ASARCO, Inc. Globe Plant (EPA ID COD007063530).

[339] ASARCO Ray Hayden (MSHA ID 0200150), ASARCO Silver Bell (MSHA ID 0200134), Freeport McMoran Tyrone (MSHA ID 2900159), Rio Tinto Kennecott Magna/Kennecott North (MSHA ID 4200149), Rio Tinto Kennecott Copperton/Kennecott South (MSHA ID 4201996), Freeport McMoran Morenci (MSHA ID 200024), Energy Fuels White Mesa Mill (MSHA ID 4201429), Materion Delta (MSHA ID 4200706), Molycorp Mountain Pass (MSHA ID 402542).

groundwater had high concentrations of sulfate and uranium.[340] Although copper operations continue at this mine, CERCLA removal actions have addressed contamination from former tailings impoundments and process ponds.

Research into additional sites revealed further evidence of releases due to leaching activity. For example, the Torch Lake Copper Mines (MID980901946), located in Keweenaw Peninsula in Michigan, discharged stampsands the operator had leached for copper between 1868 and 1968 that reduced Torch Lake's volume by 20 percent and dramatically altered the shoreline. In addition, lesions and tumors were found on fish caught in the lake. In 1972, the operator discharged 27,000 gallons of leaching liquor into the lake.[341]

Currently Operating Facilities

Out of the nine current sites in the reviewed sample that identified acid leach and SX/EW as a process, evidence of related contamination was present at five sites;

- The **ASARCO[342] Ray Hayden** (MSHA ID 0200150) mine is located near Hayden, Arizona. ASARCO Ray Hayden operations include leaching facilities, an open-pit copper mine, milling operations, a solvent extraction plant, and an electrowinning plant. The facility is conducting cleanup under a 2008 CERCLA administrative consent order (EPA ID AZD008397127), for contamination potentially dating back to the beginning of operations in 1911. Several recent releases occurred at the site, most of them due to the failure of the leachate collection systems during heavy rain. During 1990-1993, at least 19 spills of hazardous materials were reported, typically either chronic seepage from leaching facilities or accidental discharges from dams, pipelines and ponds. For example:
    - In 1990, a rainstorm overwhelmed several dams and the screens leading to the solution collection pipelines became clogged with debris. As a result, copper-laden leachate solutions overflowed the dams, releasing approximately 324,000 gallons to Mineral Creek.[343]
    - In 1991, a broken pipeline caused 150,000 gallons of leach solution to discharge to Mineral Creek. Later that year, an electrical failure led to another release of 1,500 gallons of solution.[344]

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[340] U.S. Army Corps of Engineers, *Preliminary Assessment/Site Inspection Report: Cyprus Tohono Mine, Casa Grande AZ* USACE Contract No.: DACA45.98.D0004 Task Order 25 (Washington, DC: U.S. Government Printing Office, 2003).

[341] U.S. Environmental Protection Agency Region V, *Record of Decision: Decision Summary, Torch Lake Superfund Site Operable Unit II, Houghton County, Michigan* (Washington, DC: U.S. Government Printing Office, 1993).

[342] Prior to its 2005 Chapter 11 Bankruptcy, "ASARCO" was the abbreviation for the American Smelting and Refining Company. After reorganization, the emerging company's name was ASARCO, LLC.

[343] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

[344] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

- In 1993, a bulldozer struck a leachate solution pipeline resulting in the release of 7,200 gallons of copper sulfate solution to Mineral Creek.[345]

These releases resulted in water quality degradation at the site and visible impacts on Mineral Creek – the cobble and gravel substrate in the nearby streambed was coated with a blue-green layer of copper oxides. [346]

- The **ASARCO Silver Bell** (MSHA ID 0200134) mine is located near Marana, Arizona. Leaching operations at Silver Bell occurred between 1960 and 1993. During site inspections conducted in 1993, the Arizona Department of Environmental Quality (ADEQ) observed a stream originating at the base of an active leach dump near El Tiro Pit. Samples revealed multiple water quality violations from this leach dump, including contamination from selenium, zinc, cadmium, and copper, which resulted in surface water quality degradation.[347]
- The **Freeport McMoran Tyrone** (MSHA ID 2900159) mine is located near Silver City, New Mexico. The Tyrone mine is a porphyry copper deposit that uses leaching and an SX/EW plant to produce copper. Several documented spills occurred at the site, mostly due to pipeline failures or seepage. For example:
    - In 1997, 65,000 gallons of raffinate leaked from a ruptured weld.[348]
    - In 2003, maintenance activity on a pipeline system led to 2,600 gallons of raffinate spilling.[349]

At least five other related spills were reported between 1994 and 2012. These releases have resulted in contaminated groundwater and surface water throughout the mine's area, and a 2012 groundwater assessment concluded that groundwater seepage from the Tyrone Mine will require water treatment in perpetuity.[350]

- The **Rio Tinto Kennecott Copperton/ Kennecott South** (MSHA IDs 4200149 and 4201996) mine is located southwest of Salt Lake City, Utah. The Kennecott Copper Mine

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[345] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

[346] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

[347] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

[348] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012). Accessed December 7, 2015, at https://www.earthworksaction.org/files/publications/Porphyry_Copper_Mines_Track_Record_-_8-2012.pdf.

[349] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012).

[350] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012).

is an open-pit copper mine. Acid leachate has been released numerous times over the years: from 1965-1991, reservoirs used for storing excess surface and leach waters overflowed in heavy rainfall events. In addition, on one occasion a leak in the leach water collection system resulted in a plume of contaminated groundwater.[351]

- The **Freeport McMoran Morenci** (MSHA ID 200024) mine is located northeast of Safford, Arizona. The Morenci mine is an open-pit copper mine with leaching, solvent extraction, and electrowinning operations. It has been operating since 1872. Twenty-one releases were reported between 1992 and 2008, with the vast majority of spills related to pipeline spills and equipment failures. Recent examples include:
    - In 2006, 3,000 pounds of sulfuric acid was released from a pipeline break. That same year, 1,127 pounds of material was released from another pipeline break, and a third pipeline break released rich electrolyte with an acid content of 1,057 pounds.[352]
    - In 2007, a power failure resulted in the release of 1,200,000 gallons of pregnant leach solution.[353]
    - In 2008, a pipeline spill released 186,000 gallons of sulfuric acid and trace elements into Chase Creek, lowering the pH and increasing copper and zinc concentrations for more than two miles downstream.[354]

  Many other releases of sulfuric acid and raffinate from pipelines occurred as well. The cumulative impacts related to the Morenci mine were found to have injured surface waters, terrestrial habitat and wildlife, and migratory birds.[355]

Based on the available documentation, primary concerns for acid leach and SX/EW are proper reclamation of spent dump or heap leach piles, maintenance of equipment, and ensuring that systems are prepared for rainfall events. The most common cause of releases was pipe failure, with chronic seepage from disposal areas, other equipment failures, and weather-related discharges also causing contamination.

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[351] U.S. Environmental Protection Agency, *Record of Decision, Kennecott North Zone Site, Kennecott South Zone Site* (Washington, DC: U.S. Government Printing Office, 2002).

[352] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012).

[353] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012).

[354] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012).

[355] Bonnie Gestring, *U.S. Copper Porphyry Mines Report: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures* (Washington, DC: Earthworks, July 2012).

G. Pyrometallurgical Processes

Introduction

Pyrometallurgy includes types of mineral processing that use heat to concentrate metals and remove impurities from ore. These processes generally involve oxidizing sulfides into oxides and reducing oxides into metals using a reducing agent such as carbon-based compounds.[356] Many metals, such as aluminum, copper, chromium, gold, iron, lead, nickel, platinum, and silver are commonly concentrated through pyrometallurgical processes, which include drying, calcining, roasting, smelting, and refining.

Historically, pyrometallurgical processes have been associated with significant environmental and human health effects because of their production of criteria air pollutants as well as waste that may include trace elements.[357] As such, they are often regulated by industry-specific requirements under the CAA. Releases of environmental contaminants that appear associated with smelting and related activities, however, continue to occur at currently operating facilities. At the same time, the smelting industry in the U.S. is declining and certain subsets of the industry (such as lead smelting) have closed U.S. operations entirely and/or moved their operations to other countries, at least in part because of more stringent environmental regulations.[358]

Past and Current Use

Simple roasting (exposure to reactive gas) and smelting (melting to remove impurities) processes have existed since prehistoric times, when early humans discovered that smelting could help them concentrate copper and produce bronze. Iron smelting was developed over the 2nd millennium BCE, when new furnace designs enabled the generation of higher temperatures required for iron smelting. Technological advances over the next millennia included the invention of the blast furnace in the 1100s and the invention of the reverberator furnace in the late 1600s, both of which are still in use today. Other advances such as puddling and rolling techniques made these types of furnaces increasingly efficient. By the Industrial Revolution, production capacity had increased greatly.[359]

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[356] Kawatra, S. Komar, "Primary Metal Production," lecture delivered for a class given at Michigan Technological University. Accessed November 5, 2015, at: http://www.chem.mtu.edu/chem_eng/faculty/kawatra/CM2200_Primary_Metals.pdf.

[357] U.S. Environmental Protection Agency, *Sector Notebook Project: Profile of the Nonferrous Metals Industry* (Washington, DC: U.S. Government Publishing Office, 1995).

[358] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[359] F. Habashi, "Fire and the Art of Metals: A Short History of Pyrometallurgy," *Mineral Processing and Extractive Metallurgy* 114:3 (2005), p. 165-71.

Today, various forms of smelting operations are used to process concentrates containing copper, chromium, gold, iron, lead, platinum, silver, tin, and zinc, among other metals.[360] Smelting can introduce pollutants like sulfur dioxide and trace elements, discharged as residue from air filtration systems or from furnace slag.[361]

In the recent decades, concerns about environmental consequences associated with smelting have resulted in the decrease and ultimate closure of some smelting operations in the U.S., particularly primary lead and aluminum smelters. On November 2, 2015, Alcoa Inc. announced that it would reduce its aluminum smelting capacity by 503,000 metric tons by the end of March 2016.[362] This reduction, equivalent to 31 percent of total primary aluminum production in the U.S., will have a significant impact on smelting in the country.[363] U.S. aluminum production will likely continue to decrease: falling aluminum prices are leading primary aluminum production to move to countries which produce aluminum cheaper.[364] For example, China is expected to account for 55 percent of aluminum production in 2015, up from 24 percent in 2005.[365]

Pyrometallurgical processing for lead has halted completely in the United States. In 2013, the last primary lead smelter in the United States (Doe Run Company's operation in Herculaneum, MO) closed. Pyrometallurgical processing as a whole is declining in the U.S., and it is estimated that hydrometallurgical processing (e.g., leaching and solvent extraction) will start to replace smelting in the coming decades.[366]

Technical Description

Pyrometallurgical processing generally occurs after beneficiation of the ore (such as crushing, grinding, or flotation) has taken place. Various pyrometallurgical processes are often carried out in succession, as early steps can help prepare the ore for further pyrometallurgical processing or

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[360] U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995).

[361] Hilman C. Ratsch, *Heavy-Metal Accumulation in Soil and Vegetation from Smelter Emissions* (Washington, DC: U.S. Government Printing Office, 1974).

[362] "Alcoa Cuts Back on Metal Making as Aluminum Extends Price Slump," Bloomberg Business, November 2, 2015. Accessed November 6, 2015: http://www.bloomberg.com/news/articles/2015-11-02/alcoa-scales-back-metal-making-as-aluminum-extends-price-slump

[363] "A 127-Year-Old U.S. Industry Collapses Under China's Weight," Bloomberg Business, November 3, 2015. Accessed November 6, 2015: http://www.bloomberg.com/news/articles/2015-11-03/when-a-127-year-old-u-s-industry-collapses-under-china-s-weight.

[364] Aluminum prices have fallen 27 percent in the last year alone. See: "A 127-Year-Old U.S. Industry Collapses Under China's Weight," Bloomberg Business, November 3, 2015. Accessed November 6, 2015: http://www.bloomberg.com/news/articles/2015-11-03/when-a-127-year-old-u-s-industry-collapses-under-china-s-weight.

[365] "A 127-Year-Old U.S. Industry Collapses Under China's Weight," Bloomberg Business, November 3, 2015. Accessed November 6, 2015: http://www.bloomberg.com/news/articles/2015-11-03/when-a-127-year-old-u-s-industry-collapses-under-china-s-weight.

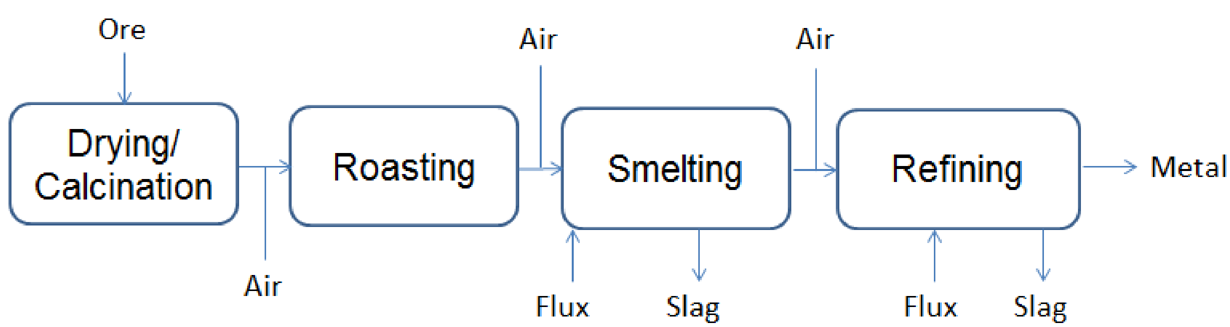
[366] National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

other processing techniques such as cyanidation or hydrometallurgical techniques. Early steps generally include some combination of drying, calcination and roasting. Smelting occurs after these initial steps, once the ore has been made more suitable for reduction. After smelting, if the ore is still in need of further purification, the final step consists of refining, which can refer to a wide range of techniques that span both hydrometallurgical and pyrometallurgical methods.[367]

Additives during pyrometallurgical processing are known as fluxes; their purpose is to combine with waste products (apart from gases) and make them easier to separate from the metal product at the working temperature. For example, some ores include waste material that has a high melting point, making it difficult to separate. In these cases, a flux such as lime might be added to combine with the unwanted mineral matter in the ore (gangue), generating a slag with a lower melting point that is easier to handle and separate from the metal product.[368]

The sections that follow summarize the major pyrometallurgical processes. Exhibit 1.F.1. shows these processes in a flow chart.

Exhibit 1.F.1. Simplified Flow Chart of Pyrometallurgical Processing[369]



Drying and Calcination

Drying and calcination describe processes through which mineral ores are heated to release volatile compounds, including water and oxygen, in the absence of additional gas, in order to increase the ratio of target substance to the rock in which it is contained. It is usually the first pyrometallurgical process to take place, and it usually requires no additives. The calcination process derives its name from the decomposition of limestone (*calcium carbonate*) into lime (*calcium oxide)*, although it can be used to describe other processes where volatiles are removed as a gas, including the decomposition of zinc carbonate to zinc oxide, and bauxite (*aluminum hydroxide*) into a form of aluminum (*aluminum oxide*) that is ready to undergo the Hall-Heroult

[367] Jeanne Mager Stellman, "Chapter 82 - Metal Processing and Metal Working Industry," *Encyclopaedia of Occupational Health and Safety*, (Geneva: International Labour Office/ ILO/ International Labour Organisation, 1998), Volume 4.

[368] S. Ramachandra Rao, *Resource Recovery and Recycling from Metallurgical Wastes* (Amsterdam: Elsevier, 2006).

[369] Adapted from Jain, Ravi, Zengdi Cui, and Jeremy Domen, *Environmental Impact of Mining and Mineral Processing: Management, Monitoring, and Auditing Strategies* (Oxford: Elsevier Butterworth-Hein, 2015).

process described below.[370] Calcination can produce air emissions that contain the volatile compounds released from the ore, including sulfur dioxide, water vapor, and other forms of particulate matter.

Roasting

Unlike drying and calcination, which do not involve adding gases, roasting involves heating the ore and exposing it to a reactive gas in order to remove unwanted compounds present in the ore. Roasting is usually used to convert sulfides to oxides by reaction with air, although the process can also use other gases, such as chlorine. The ore particles react with the gas, and the gaseous waste product is carried away, leaving behind concentrated ore particles. Since the particles do not melt, the reaction starts on the particle surface and gradually works into the particle core.[371] Because the roasting process usually involves removing sulfides from the ore, the most significant pollutant produced is sulfur dioxide, which is regulated under the CAA.

Smelting

Smelting is the process through which ore is melted to remove impurities and further concentrate the final product, generating a molten metal, slag, and waste gas. The impurities are either carried off in the slag or burned off as gas and particulates. In some furnaces, the roasting and smelting processes are combined.

Smelting processes vary greatly based on the ore. The smelting processes for aluminum, copper, and iron all have specific inputs that facilitate the concentration of the metals of interest based on their chemical properties. Generally, however, additives allow the molten metal to be separated and removed from other materials. One example of a smelting process is the Hall-Heroult process, which was invented in the late 1800s and is still the primary method for aluminum smelting. The process dissolves aluminum oxide in a molten salt bath and applies a low voltage current. Molten aluminum is then reduced and isolated, and hydrogen fluoride and other wastes are discarded. During this process, electrical resistance is used to generate temperatures above one thousand degrees Celsius.[372]

Refining

Unlike smelting, refining involves no chemical change to the raw material – it merely purifies the final material instead of altering its makeup. Refining includes a wide range of processes involving both pyrometallurgical and hydrometallurgical techniques, as it refers to any process

[370] "Process Description Calcination," DGEngineering. Accessed November 5, 2015, at: http://www.dgengineering.de/Rotary-Kiln-Processes-Calcination.html.

[371] Kawatra, S. Komar, "Primary Metal Production," lecture delivered for a class given at Michigan Technological University. Accessed November 5, 2015, at: http://www.chem.mtu.edu/chem_eng/faculty/kawatra/CM2200_Primary_Metals.pdf.

[372] Kawatra, S. Komar, "Primary Metal Production," lecture delivered for a class given at Michigan Technological University. Accessed November 5, 2015, at: http://www.chem.mtu.edu/chem_eng/faculty/kawatra/CM2200_Primary_Metals.pdf.

that helps to increase the grade of a metal.[373] A couple examples of refining methods, which can vary greatly, include the Pattison and the Parkes processes.

Potential Sources of Hazardous Substances

A major environmental concern with pyrometallurgical processes across the board has been the release of sulfur dioxide and other noxious gases and particulate matter released from flues in the furnaces. Other byproducts include liquid waste, slag, sludge, and spent potliners. See Exhibit 1.F.2. for a summary of typical wastes or byproducts associated with pyrometallurgical processing of the major commodities processed in the U.S.

Air Emissions

The most common gaseous release from pyrometallurgical processes is sulfuric dioxide gas (SO_2), although releases have declined with regulations and continuing advances in engineering over the last several decades. Annual releases of SO_2 from metal processing totaled 4,775 thousand tons in 1970, but by 1980 emissions were down to 1,842 thousand tons. Continuing this trend, emissions decreased to 530 thousand tons by 1995, and 144 thousand tons in 2014.[374] Current practices require that these emissions be captured, and they are now typically converted to sulfuric acid.

More efficient and environmentally-conscious smelting processes have been developed as technologies and environmental regulations have evolved. Electrostatic precipitators, for example, use electric charges to attract small particles out of flue-based discharges, while baghouses use fine fabric meshes to filter out similar sets of particulate matter. Use of these technologies can remove 99 percent of toxic metal particles and 99.99 percent of dust.[375,376] Ideally, the baghouse dust is recycled. If not, it is disposed of in a hopper.[377] The dust is a hazardous waste that is subject to solid waste management guidelines.

[373] Ahindra Ghosh, *Principles of Extractive Metallurgy*, Second Edition, (New Delhi: New Age International, 1991).

[374] "National Emissions Inventory Air Pollutant Emissions Trends Data: 1970-2014 Average annual emissions, all criteria pollutants," U.S. Environmental Protection Agency, updated March, 2015. Accessed November 5, 2015, at https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data.

[375] United Nations Environment Programme, United Nations Industrial Development Organization, and the World Bank Group, *Pollution Prevention and Abatement Handbook, Airborne Particulate Matter: Pollution Prevention and Control* (Washington DC: World Bank, 1998).

[376] T. Moore, "Hazardous Air Pollutants: Measuring in Micrograms," *EPRI Journal* 19:1 (1994), p. 33-37.

[377] U.S. Environmental Protection Agency, *Air Pollution Cost Control Manual*, Sixth Edition (Washington, DC: U.S. Government Printing Office, 2002), Section 6, Chapter 1.

Exhibit 1.F.2. Potential Releases Associated with Pyrometallurgy[378, 379]

METAL	PROCESS	MATERIAL INPUT	AIR EMISSIONS	LIQUID WASTE	OTHER WASTES
Copper	Copper smelting	Copper concentrate, siliceous flux	Sulfur dioxide, particulate matter containing arsenic, antimony, cadmium, lead, mercury and zinc	None	Acid plant blowdown slurry/sludge, slag containing iron sulfides, silica
Lead	Lead smelting	Lead sinter, coke	Sulfur dioxide, particulate matter containing cadmium and lead	Plant washdown wastewater, slag granulation water	Slag containing impurities such as zinc, iron, silica and lime, surface impoundment solids
Zinc	Zinc calcining	Zinc ore, coke	Sulfur dioxide, particulate matter containing zinc and lead	None	Acid plant blowdown slurry
Aluminum	Alumina calcination	Aluminum hydrate	Particulates and water vapor	None	None
	Primary electrolytic aluminum smelting	Alumina, carbon anodes, electrolytic cells, cryolite	Fluoride—both gaseous and particulates, carbon dioxide, sulfur dioxide, carbon monoxide, C2F6,CF4 and perfluorinated carbons (PFC)	None	Spent potliners
Iron	Iron smelting using a blast furnace	Iron ore or sinter, coke, limestone or dolomite	Sulfur dioxide, carbon monoxide	Coolant containing zinc, tar, and lime residue	Slag containing sulfur, magnesium, and/or silicon-based compounds

378 Jeanne Mager Stellman, "Chapter 82 - Metal Processing and Metal Working Industry," *Encyclopaedia of Occupational Health and Safety*, (Geneva: International Labour Office/ ILO/ International Labour Organisation, 1998), Volume 4.

379 U.S. Environmental Protection Agency, “Iron and Steel,” in *Identification and Description of Mineral Processing Sectors and Waste Streams* (Washington, DC: U.S. Government Printing Office, 2012). Accessed November 5, 2015, at https://archive.epa.gov/epawaste/nonhaz/industrial/special/web/pdf/id4-hfa.pdf

Several mining companies also have flue gas desulfurization (wet scrubber) systems at their sites. These alkaline slurries chemically neutralize the acid gas before it is released into the atmosphere, often removing upwards of 90 percent of SO_2 from flue gases.[380] Scrubbing processes also pull many of the other pollutants out of the waste gas, including arsenic, lead, and zinc.

Liquid Waste

Wastewater generated by the wet scrubbing and slag cooling processes is a major source of liquid waste in pyrometallurgical processes. Though most wastewater from the wet scrubbing process can be recycled for future use, smelters in the 1970s and early 1980s would often discharge or "blow down" a small amount of wastes in order to minimize corrosion and buildup of solids. Over the next ten years, several plants abandoned this practice, instead using various separation techniques to extract target metals from the solid wastes. Other plants began to neutralize these wastes and discharge them into lined surface impoundments or wastewater treatment facilities.[381] By the mid-1990s, lead smelters had ceased storing wastewater from the slag quenching process in unlined surface impoundments, and instead recycled the solids back into the smelting process.[382] Other smelters adopted similar approaches over this time, either recycling sludges back into the smelting process or neutralizing these wastes with lime or magnesium before selling the resulting product or sending it to special landfills.[383]

Other Wastes

Slag, the collection of compounds removed from the molten metal product, is created during smelting. Some types of slag can be commercial products and are considered relatively benign; for example, iron and steel slag can be sold for use in construction or cement.[384]When slag is produced, however, it is very hot. Slag that is not intended for reuse can be air cooled, but slag that may be sold often requires quenching with water, producing wastewater that can contain harmful substances (discussed above). In addition, many types of slag have been a source of some environmental contamination. Nonferrous slag in particular contains elements that are of

[380] G. Hilson, "Pollution prevention and cleaner production in the mining industry: an analysis of current issues," *Journal of Cleaner Production* 8 (2000), p. 119-126.

[381] U.S. Environmental Protection Agency, Office of Solid Waste, *Technical Background Document: Remanded Smelting Wastes* (Washington, DC: U.S. Government Printing Office, 1995). Accessed at: http://www.epa.gov/osw/nonhaz/industrial/special/mining/minedock/smelt/remsmelt.pdf

[382] U.S. Environmental Protection Agency, Office of Solid Waste, *Technical Background Document: Remanded Smelting Wastes* (Washington, DC: U.S. Government Printing Office, 1995).

[383] U.S. Environmental Protection Agency, Office of Solid Waste, *Technical Background Document: Remanded Smelting Wastes* (Washington, DC: U.S. Government Printing Office, 1995).

[384] D.M. Proctor, E.C. Shay, K. A Fehling, and B.L. Finley, "Assessment of human health and ecological risks posed by the use of steel-industry slags in the environment," *Human Ecological Risk Assessment* 8 (2002), p. 681–711.

concern – some types of slag contain concentrations of aluminum, chromium, copper, iron, manganese, lead, and zinc that exceed EPA soil screening levels for human contact.[385]

Blowdown slurry and sludge, which result from the sulfur recovery process, qualifies as a hazardous waste and is regulated under RCRA.[386]

State and Federal Regulations

At both the federal and state level, environmental regulations address potential environmental releases from pyrometallurgical processing, particularly smelting. While some smelting wastes are excluded from regulation under RCRA Subtitle C, many are regulated as hazardous wastes and face strict reporting and management requirements. Additionally, the CAA and CWA regulate releases to air and water, including industry-specific guidelines for pyrometallurgical processing of minerals.

Federal Regulations

Nonferrous metal manufacturing facilities, including smelting and refining operations for several primary metals must comply with ELGs under the CWA.[387] Processing facilities each obtain permits under NPDES, which specify water quality requirements and operating standards related to process wastewater and stormwater from industrial activity based on ELGs.

Solid wastes from pyrometallurgical processes include residues from air filtration systems and furnace slags from thermal processing. RCRA exempts many types of mineral processing wastes under the Bevill Amendment, including several types of smelting and refining wastes.[388] State and local governments implement solid waste management guidelines under RCRA Subtitle D. Emissions control dust from baghouses in iron and steel production (waste code K061) and spent potliners from the Hall-Heroult process from aluminum reduction (waste code K088) are specifically regulated as RCRA hazardous wastes.

As outlined in Exhibit 1.F.3., the CAA, passed in 1970 and amended in 1977 and 1990, regulates air emissions from many mineral processing sectors at the federal level. Section 111 of the CAA requires the EPA to establish federal emission standards for industrial source categories which cause or contribute significantly to air pollution. Accordingly, EPA promulgated NSPS at 40

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385 Nadine M. Piatak, Michael B. Parsons, and Robert R. Seal, "Characteristics and Environmental Aspects of Slag: A Review," *Applied Geochemistry* 57 (2015), p. 236-66.

386 Jeanne Mager Stellman, "Chapter 82 - Metal Processing and Metal Working Industry," *Encyclopaedia of Occupational Health and Safety*, (Geneva: International Labour Office/ ILO/ International Labour Organisation, 1998), Volume 4.

387 Regulated facilities include aluminum smelting, copper smelting, electrolytic copper refining, lead smelting, and rare earths ores processing. 40 CFR Part 421. Promulgated in 1974-1976, revised in 1980-1990. See: "Nonferrous Metals Manufacturing Effluent Guidelines," U.S. Environmental Protection Agency. Accessed November 5, 2015, at: http://water.epa.gov/scitech/wastetech/guide/nfmm/.

388 U.S. Environmental Protection Agency, Office of Solid Waste, *Technical Background Document: Remanded Smelting Wastes* (Washington, DC: U.S. Government Printing Office, 1995).

Exhibit 1.F.3. National Emission Standards for Hazardous Air Pollutants Relevant to Hardrock Mining and Mineral Processing

INDUSTRIAL SECTOR	NESHAP	NSPS	CITATIONS
Ferroalloys production	✓	✓	**NESHAP:** 40 CFR 63, Subpart XXX (*major sources*); 40 CFR 63 Subpart YYYYYY(*area sources*) **NSPS:** 40 CFR 60 Subpart Z, 60.260-266
Iron and steel processing[389]	✓	✓	**NESHAP:** 40 CFR 63, Subpart EEEEE (Iron and steel foundries - major sources); 40 CFR Part 63 Subpart YYYYY (Electric Arc Steelmaking Facilities – area sources); 40 CFR 63, Subpart ZZZZZ (area sources); 40 CFR 63 Subpart RRRRR (Taconite iron ore processing - major sources) **NSPS:** 40 CFR 63, Subpart YYYYY (Electric Arc Furnace Steelmaking Facilities – area sources)**;** 40 CFR 60 Subpart AA, and AAa, 60.270-276 (Electric arc furnaces – major sources); 40 CFR 60 Subpart Na, 60.140a-145a (Secondary emissions from basic oxygen process steelmaking facilities constructed after 1/20/1983)
Gold mine ore processing and production	✓		**NESHAP:** 40 CFR 63, Subpart EEEEEEE *(area sources)*
Primary aluminum reduction plants	✓	✓	**NESHAP:** 40 CFR 63, Subpart LL (*major sources*) **NSPS**: 40 CFR 60 Subpart S, 60.190-60.195
Primary lead production	✓	✓	**NESHAP:** 40 CFR 63, Subpart TTT (*major sources*) **NSPS:** 40 CFR 60 Subpart R, 60.180-186
Primary copper production	✓	✓	**NESHAP:** 40 CFR 63, Subpart QQQ (Primary copper – major sources); 40 CFR 63, Subpart EEEEEE (Primary copper smelting – area sources); 40 CFR 63, Subpart ZZZZZZ (Aluminum, copper, and other nonferrous foundries - area sources); 40 CFR 63, Subpart J (PVC and copolymers production, primary copper smelting, secondary copper smelting, and primary nonferrous metals: zinc, cadmium, and beryllium) **NSPS:** 40 CFR 60 Subpart P, 60.160-166 (*Primary copper smelters*)

[389] While the RCRA exempts many types of mineral processing wastes, emissions control dust from baghouses in iron and steel production is specifically regulated as RCRA hazardous waste (waste code K061).

INDUSTRIAL SECTOR	NESHAP	NSPS	CITATIONS
Primary magnesium refining	✓		**NESHAP:** 40 CFR 63, Subpart TTTTT (Primary magnesium refining - major sources)
Other nonferrous metals processing	✓	✓	**NESHAP:** 40 CFR 63, Subpart ZZZZZZ (Aluminum, copper, and other nonferrous foundries - area sources); 40 CFR 63, Subpart J (PVC and copolymers production, primary copper smelting, secondary copper smelting, and primary nonferrous metals: zinc, cadmium, and beryllium); 40 CFR 63, Subpart GGGGGG (Primary nonferrous metals: zinc, cadmium, and beryllium – area sources) **NSPS:** 40 CFR 60 Subpart Q, 60.170-176 (*Primary zinc smelters*); 40 CFR 60 Subpart LL, 60.380-386 *(Metallic Mineral Processing Plants)*
Nonmetallic Mineral Processing Plants		✓	**NSPS:** 40 CFR 60 Subpart OOO, 60.670-676 *(Nonmetallic mineral processing plants)*
Phosphates	✓	✓	**NESHAP:** 40 CFR 63, Subparts AA and BB (Phosphoric acid manufacturing and phosphate fertilizers) **NSPS:** 40 CFR 60 Parts T-X *(Phosphate fertilizer industry)*; 40 CFR 60 Subpart NN, 60.400-404 *(Phosphate rock plants)*

CFR Part 60. These standards apply to sources that have been constructed or modified since the promulgation of each standard.

Section 112 of the CAA addresses emissions of hazardous air pollutants, which are known or suspected to cause cancer or other serious health effects. The 1990 CAA Amendments directed the EPA to issue technology-based standards for industrial categories emitting hazardous air pollutants. Consequently, over the past 25 years, EPA has promulgated NESHAPs at 40 CFR Part 63 for multiple industrial sources. Major sources, which emit 10 tons per year of a single hazardous air pollutant or 25 tons per year of any combination of hazardous air pollutants, must follow hazardous air pollutant standards that require Maximum Achievable Control Technology (MACT) standards. Non-major sources may be regulated as "area sources." Specific control requirements vary by source. Requirements include:

- Technology-based performance standards
- Operational requirements
- Emission limits

Generally, state and local air pollution control agencies are responsible for implementation and enforcement of these CAA air standards. EPA reviews and approves state programs to maintain a consistent national regulatory framework.

The following exhibit illustrates the specific applicability of NSPS and NESHAP regulations to primary mineral processing facilities.

State Regulations

Many states have delegated authority under the CAA to regulate industrial sources of air pollution. Five states have partial delegated authority for the industry-specific NESHAP,[390] while three have full delegated authority.[391] For NSPS implementation, four states have partial delegated authority[392] and three have full delegated authority.[393] EPA implements the NSPS programs for one state.[394] Five states (Arizona, California, Idaho, Minnesota, and Nevada) also have separate state-level air toxics programs. Of these, we identified several programs with technical standards specifically designed for primary processing operations. We summarize them below:

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[390] Alaska, Arizona, California, Idaho, and Nevada.

[391] Minnesota, Montana, and Utah. From: "Clean Air Act," The Environmental Council of the States (ECOS) State Delegations. http://www.ecos.org/section/states/enviro_actlist/states_enviro_actlist_caa

[392] Alaska, Arizona, California, and Nevada.

[393] Minnesota, Montana, and Utah.

[394] Idaho.

- California Emissions of Toxic Metals from Non-Ferrous Metal Melting Airborne Toxic Control Measures: Non-ferrous metal melting furnaces, including reverberatory, induction, and direct arc furnaces, must have an emissions collection system, undergo testing, and use fugitive emissions control systems. (7 CCR 93107)
- Nevada Mercury Control Program: In 2002, Nevada's Voluntary Mercury Air Emission Reduction Program established emission reduction goals.[395] Nevada also requires additional MACT for mercury emissions on thermal units at existing and new metal mines. All users of thermal units at existing metal mines must apply for a Mercury Operating Permit to construct before constructing thermal units. (NAC 445B.3611 – 445B.3689)

Non-Operating Sites and Currently Operating Facilities

Non-Operating Sites

Smelting was identified as a practice at 12 sites of the sample of 29 non-operating sites reviewed.[396] The most common commodities processed at these sites were lead, zinc, copper, gold, and silver.[397] Releases directly related to smelting were identified at three of the 12 sites in this sample.[398] These releases came in the form of airborne emissions, including lead, cadmium, arsenic, and particulate matter, and occurred both before and after the promulgation of air regulations:

- **National Zinc Corp.** (EPA ID OKD000829440): The National Zinc Corporation operated a zinc smelter in Bartlesville, Oklahoma from 1907 to 1976.[399] The smelter did not have air emission controls, which allowed emissions to be deposited downwind.[400] Blood lead studies in 1991 and 1992 funded by Agency for Toxic Substances and Disease Registry (ATSDR) and performed by Oklahoma State Department of Health (OSDH), now ODEQ) indicated that approximately 14 percent of the children in the contaminated

[395] In 2003, Nevada produced 82 percent of the gold mined in the United States. The TRI for Nevada indicates that four Nevada mining companies emitted roughly 90 percent of the state's reported mercury air emissions in 2001. For more information, see: EPA. 2010. Fact Sheet: Final Rule to Reduce Mercury Emissions from Gold Mine Ore Processing and Production Sources. Accessed February 13, 2015 at http://www.epa.gov/ttn/atw/area/gold_mines_fs_121610.pdf

[396] Tex-Tin Corp. (EPA ID TXD062113329), Asarco, Inc. (Globe Plant) (EPA ID COD007063530), California Gulch (EPA ID COD980717938), Summitville Mine (EPA ID COD983778432), Bunker Hill Mining & Metallurgical Complex (EPA ID IDD048340921), Eagle Zinc Co. Div. TL Diamond (EPA ID ILD980606941), East Helena Site (EPA ID MTD006230346), Omaha Lead (EPA ID NESFN0703481), Shieldalloy Corp. (EPA ID NJD002365930), Li Tungsten Corp. (EPA ID NYD986882660), National Zinc Corp. (EPA ID OKD000829440), Tar Creek (Ottawa County) (EPA ID OKD980629844).

[397] Seven sites processed zinc, seven sites processed lead, five sites processed copper, five sites processed gold, and five sites processed silver.

[398] East Helena Site (MTD006230346), Omaha Lead (NESFN0703481), National Zinc Corp. (OKD000829440)

[399] "Superfund Program: National Zinc Corp., Bartlesville, OK," U.S. Environmental Protection Agency. Accessed November 11, 2015: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0601010.

[400] "Superfund Program: National Zinc Corp., Bartlesville, OK," U.S. Environmental Protection Agency. Accessed November 11, 2015: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0601010.

area had elevated levels of blood lead greater than 10 micrograms per deciliter. Contaminants of concern at the National Zinc Corporation site are lead and cadmium in air dispersion and slag material contaminated soils.

- **Omaha Lead** (EPA ID NESFN0703481): The Omaha Lead site occupies 20 square miles in downtown Omaha, Nebraska.[401] Two lead smelting facilities operated on the site. ASARCO smelted and refined lead from the early 1870s until 1996.[402]

The ASARCO facility emitted lead and other trace elements from smokestacks. Wind transported the pollutants, which were eventually deposited on nearby land.[403]Ambient air quality tests, conducted by the Douglas County Health Department (DCHD) in 1984, measured lead concentrations exceeding the ambient standard of 1.5 micrograms per cubic meter.[404] The highest measurement by DCHD was 6.57 micrograms per cubic meter.[405] DCHD found elevated blood lead levels in children living near the Omaha Lead site, compared to the national average.[406] Soil sampling indicated significant lead contamination in the surrounding area.[407] The site was added to the NPL list on April 30, 2003.[408]

- **East Helena Site** (EPA ID MTD006230346): The East Helena site occupies 8.4 square miles near East Helena, Montana. The site included a primary lead smelter and a primary zinc smelter, which emitted lead, cadmium, and arsenic compounds during its operational period of 1888 until 2001.[409] Despite mitigation steps, including the installation of an acid plant to control sulfur dioxide emissions, the facility exceeded sulfur dioxide emissions in 1978 and 1980.[410] In 1981, the facility added a tall stack to the blast furnace baghouse to reduce ground-level emissions. The site was added to the NPL in 1983.

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[401] U.S. Environmental Protection Agency, *Omaha Lead Site Interim Record of Decision* (Washington, DC: U.S. Government Printing Office, 2004).

[402] "Superfund Sites – NPL. Omaha Lead," U.S. Environmental Protection Agency. Accessed October 30, 2015: http://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0703481.

[403] "Superfund Sites – NPL. Omaha Lead," U.S. Environmental Protection Agency. Accessed October 30, 2015: http://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0703481.

[404] U.S. Environmental Protection Agency, *Omaha Lead Site Interim Record of Decision* (Washington, DC: U.S. Government Printing Office, 2004).

[405] U.S. Environmental Protection Agency, *Omaha Lead Site Interim Record of Decision* (Washington, DC: U.S. Government Printing Office, 2004).

[406] U.S. Environmental Protection Agency, *Omaha Lead Site Interim Record of Decision* (Washington, DC: U.S. Government Printing Office, 2004).

[407] U.S. Environmental Protection Agency, *Omaha Lead Site Interim Record of Decision* (Washington, DC: U.S. Government Printing Office, 2004).

[408] U.S. Environmental Protection Agency, *Omaha Lead Site Interim Record of Decision* (Washington, DC: U.S. Government Printing Office, 2004).

[409] "Superfund Program: East Helena Site, East Helena, MT," U.S. Environmental Protection Agency. Accessed November 11, 2015: http://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0800377.

[410] U.S. Environmental Protection Agency, *EPA Superfund Record of Decision: East Helena Site* (Washington, DC: U.S. Government Printing Office, 1989).

Currently Operating Facilities

Five of the 70 currently operating facilities reviewed use primary smelting as a processing technique.[411] Two of these facilities, ASARCO Ray Hayden Complex (MSHA IDs 0200826 and 0200150) and Rio Tinto Kennecott Bingham Canyon-Copperton-Magna (MSHA IDs 4200149 and 4201996) produce copper. Stillwater mine (MSHA ID 2401490) produces platinum, US Antimony Montana produces antimony, and Nyrstar Clarksville is the only primary zinc facility in the United States. EPA's Toxics Release Inventory (TRI) data indicate that the ASARCO Ray Hayden Complex and Nyrstar Clarksville released air emissions. ASARCO had a permit for air emissions from its smelter, although the emissions led to the presence of contaminants in higher than expected levels in two nearby towns.[412,413] Emissions from the Nyrstar facility contain compounds typical to smelting activities (e.g., zinc, cadmium, lead, and copper), available documentation does not provide direct evidence that smelting or other pyrometallurgical processes caused these releases or if Nyrstar had a permit for the releases.[414]

Releases of contaminants have been observed both before and after the promulgation of major environmental regulations, suggesting that technological advances and regulatory oversight may have not eliminated the potential for environmental contamination.

ASARCO Ray Hayden Complex (MSHA IDs 0200826 and 0200150)[415]

The ASARCO Ray Hayden Complex includes the Ray surface copper mine and concentrator and the Hayden smelter. The Ray mine began operations in 1880 and the Hayden smelter began operations in 1920. The Ray facility extracts and crushes copper ore, before it is processed and smelted at the Hayden facility.

Smelting conducted at the facility both before and after the promulgation of environmental regulations has resulted in elevated levels of lead, arsenic, and copper in nearby land. A 1,000-foot tall smokestack was constructed in 1974 to reduce ground-level emissions. Yet, air quality monitoring in the two neighboring towns, Hayden and Winkelman, Nevada, measured elevated levels of arsenic, lead, copper, cadmium, and chromium from site operations in 2013 and

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[411] Asarco Ray (MSHA IDs 0200826 and 0200150), Nyrstar Clarksville (MSHA ID Unknown), RioTinto Kennecott Bingham Canyon-Copperton-Magna (MSHA IDs 4200149 and 4201996), Stillwater Stillwater/Columbus (MSHA ID 2401490), US Antimony Montana (MSHA ID Unknown).

[412] Arizona Department of Environmental Quality, "Air Quality Permit No. 1000042 for the Asarco Hayden Smelter," October 10, 2001.

[413] U.S. Environmental Protection Agency Region 10, *Administrative Settlement Agreement and Order on Consent for Asarco Hayden Plant Site* Docket No. CERCLA-2008-13, April 15, 2008.

[414] TRI reported air emissions from the Nyrstar Facility: zinc, cadmium, lead, manganese, and copper compounds. Air emissions from the Ray Hayden Facility: arsenic, barium, antimony, zinc, mercury, selenium, nickel, cadmium, manganese, silver, chromium, cobalt, copper, and lead compounds, and sulfuric acid.

[415] "Superfund Site – Asarco Hayden Plant," U.S. Environmental Protection Agency Region 9. Accessed October 30, 2015: http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/ViewByEPAID/AZD008397127#area.

2014.[416] The facility is conducting cleanup under a 2008 CERCLA administrative consent order (EPA ID AZD008397127). As of January 2015, the facility had been in significant violation of its CAA permit for at least the past three years.[417]

Additionally, data in ERNS indicate that at least one release at the complex was directly related to smelting activity. In 2002 blowdown equipment failure of the Hayden smelter led to a release of 1.37 pounds of arsenic compounds. While other data directly linking releases at the complex to smelting are limited, there are 88 releases reported to ERNS attributed to the complex, many of them of compounds typically associated with smelting.

[416] “Asarco Hayden Plant: Site Updates and Upcoming Public Meeting,” U.S. Environmental Protection Agency Region 9. Accessed October 30, 2015: http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dc283e6c5d6056f88257426007417a2/6b0358416fdb7e3288257d9000669ee8/$FILE/70348280.pdf/Asarco%2010_14.pdf.

[417] “Enforcement and Compliance History Online (ECHO): Ray Mine Unit and Hayden Smelter (FRS ID 110000471338),” U.S. Environmental Protection Agency. Accessed October 30, 2015, at: http://echo.epa.gov/detailed-facility-report?fid=110000471338.

H. Bayer Process

Introduction

In nature, metallic aluminum is never found in its pure form; it almost always exists in the form of hydrated oxides or silicates, which are usually contained in an ore called bauxite. The Bayer process is the key industrial method for turning this ore into aluminum oxide (known as alumina), which can then undergo electrolytic smelting for further purification. The process involves dissolving the ore in a sodium hydroxide solution, which allows the alumina to be precipitated out and the waste ore to be carried away as red mud. While red mud is not classified as hazardous under RCRA Subtitle C, large volumes are produced, making proper disposal an important issue.[418] Limits for the amount of wastewater overflow and discharges from impoundments such as red mud lakes are set by the CWA ELGs for the nonferrous metals manufacturing point-source category. Louisiana and Texas, where U.S. bauxite refining facilities currently operate, also regulate red mud under solid waste regulations, requiring operating and closure standards for surface impoundments holding processing waste. Limited evidence from non-operating Superfund sites indicates that hazardous substance releases from red mud disposal areas occurred at two sites engaged in Bayer processing, leading to contamination of surrounding environment, including surface water. No evidence exists of red mud releases from currently operating facilities in the U.S., although one site received complaints regarding dust emitted from the red mud lagoons.

In addition, sodium hydroxide, used to dissolve the ore during the Bayer process, is highly corrosive and can pose human health and environmental risks if released.[419] As a hazardous process chemical, it faces handling, transportation, and management requirements under RCRA Subtitle C. Releases of sodium hydroxide due to equipment failure and operator errors have occurred historically, as well as at currently operating sites within the reviewed sample.

Past and Current Use

The Bayer process was invented in Russia in 1888 by chemist Karl Josef Bayer. It was immediately accepted into industrial practices, largely replacing the earlier Le Chatelier process and becoming the primary method of alumina production worldwide. Although improvements in engineering have decreased the costs, the Bayer process itself has remained relatively unchanged since that time, and is still used to produce nearly all of the world's alumina supply.[420]

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[418] Dietrich G. Altenpohl, *Aluminum: Technology, Applications and Environment: A Profile of a Modern Metal from Within* (Malden, MA: Wiley, 1998).

[419] "Hazardous Substance Fact Sheet: Sodium Hydroxide," New Jersey Department of Health. Accessed November 12, 2015, at http://nj.gov/health/eoh/rtkweb/documents/fs/1706.pdf.

[420] Fathi Habashi, "Bayer's Process for Alumina Production: A Historical Perspective," *Bulletin of Historical Chemistry* 17/18 (1995), p. 15-19.

Primary aluminum processing production in the United States (and thus, use of the Bayer process) reached its peak of 4,654,000 metric tons in 1980, and has been generally trending down (with some fluctuations) since then. Recent years' production ranged from 1,727,000 metric tons in 2009 to 1,946,000 metric tons in 2013.[421] Nearly all bauxite ore, the ore processed to produce aluminum, originates from overseas mining operations; thus no U.S. mining facilities produce bauxite ore.[422]

Technical Description

The Bayer process converts bauxite ore (a hydrated oxide of aluminum consisting of 30 to 56 percent alumina as well as iron, silicon, and titanium) to crystalline alumina that is suitable for electrolysis. The crude bauxite ore is crushed and ground before being mixed with a preheated solution of caustic soda (sodium hydroxide). Lime is often added at this stage to control phosphorus content and improve the solubility of alumina. This slurry is then pumped into heated pressure chambers, which dissolves the ore into sodium aluminate. Iron, titanium, and other impurities settle out of this solution, because they are not affected chemically and remain solid. These solids are the primary waste material from the Bayer process, known as red mud. They are separated from the sodium aluminate solution, washed, and then pumped to disposal areas. The washwater, which contains caustic soda, is recycled to the process.

The sodium aluminate solution is then cooled (usually by the washwater from the waste product) and seeded with alumina crystals from a previous cycle, which supersaturates the solution. This forces the alumina to precipitate out. Alumina is then washed and filtered before undergoing calcination in rotating furnaces called rotary kilns, which readies it for further processing to turn it into aluminum metal (generally through the Hall-Heroult process).[423, 424] See Exhibit 1.H.1. for a simplified diagram of the Bayer process.

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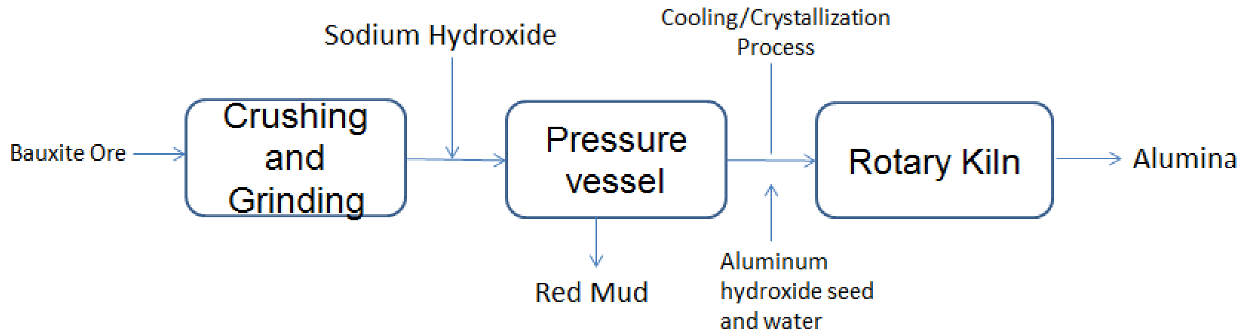
[421] "Historical statistics for mineral and material commodities in the United States: Aluminum," Thomas D. Kelly and Grecia R. Matos, U.S. Geological Survey Data Series 140, updated 2013. Accessed Nov. 10, 2015, at http://minerals.usgs.gov/minerals/pubs/historical-statistics/.

[422] "Minerals Commodity Summary: Bauxite and Alumina," U.S. Geological Survey, updated 2015. Accessed Dec. 10, 2015, at: http://minerals.usgs.gov/minerals/pubs/commodity/bauxite/mcs-2015-bauxi.pdf.

[423] Dietrich G. Altenpohl, *Aluminum: Technology, Applications and Environment: A Profile of a Modern Metal from Within* (Malden, MA: Wiley, 1998).

[424] U.S. Environmental Protection Agency, "Chapter 12: Introduction to Metallurgical Industry," in *AP 42 Emissions Factors*, Fifth Edition (Washington, DC: U.S. Government Printing Office, 1998), Volume I.

Exhibit 1.H.1. Simplified Flow Chart of the Bayer Process



Potential Sources of Hazardous Substances

The major environmental concern associated with the Bayer process is red mud, which is produced in large quantities.[425] Red mud is made up primarily of iron, aluminum, silica, calcium and sodium, but can contain other trace elements depending on the composition of the original bauxite ore. While these trace elements are generally only present in low concentrations and are rarely considered a serious threat to health, arsenic, chromium, and radium-226 could pose concerns in some cases. In addition, red mud is highly alkaline, which has negative effects on plant life in surrounding areas.[426]

Usually, red mud is deposited in large on-site surface impoundments ("red mud lakes"), where the mud settles to the bottom and the water is removed and treated. In these "lakes," the mud builds up in place and dries to a solid. After at least 25 years, these areas can be revegetated, although they generally require some topsoil modification because of the high alkalinity, salinity and sodicity (sodium content) of red mud.[427]

Releases associated with the Bayer process generally occur in three general ways. First, the berms or dikes used to contain red mud lakes can fail and release the mud itself. Second, releases can occur once the lakes have dried up. Finally, precipitation can cause elements such as arsenic and selenium to leach from the red mud, or wind erosion can release fine particles of red mud into the air. EPA investigated risks associated with these types of releases in 1990, however, and found that the potential for danger to health and the environment is generally low.[428]

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[425] Depending on the grade of the bauxite ore, the Bayer process can produce one to two times as much red mud as it does alumina. See Dietrich G. Altenpohl, *Aluminum: Technology, Applications and Environment: A Profile of a Modern Metal from Within* (Malden, MA: Wiley, 1998).

[426] U.S. Environmental Protection Agency, *Report to Congress on Special Wastes from Mineral Processing* (Washington, DC: U.S. Government Printing Office, 1990).

[427] J. Wong, "Use Of Waste Gypsum In The Revegetation On Red Mud Deposits: A Greenhouse Study," *Waste Management & Research* 11:3 (1993), p. 249-56.

[428] U.S. Environmental Protection Agency, *Report to Congress on Special Wastes from Mineral Processing* (Washington, DC: U.S. Government Printing Office, 1990).

Other hazardous releases that can stem from the Bayer process include fugitive dust from early physical processing, and sodium hydroxide. There is little evidence that fugitive dust has been a concern, and typical methods of containment from physical processing can be used to minimize these risks. Sodium hydroxide is highly corrosive and can pose human health and environmental risks if released, but as it is generally recycled back into the process, potential for releases is generally low.[429]

See Exhibit 1.H.2. for a summary of potential releases and best management practices for minimizing these risks.

State and Federal Regulations

While few regulations pertain specifically to the Bayer process, or alumina processing in general, broad regulatory frameworks address these practices at the state and federal level. See Section 2.C.4. for broader discussion of the regulations applicable to tailings (including red mud).

Federal Regulations

RCRA (the Bevill Amendment) exempts red mud from regulation as hazardous waste under RCRA Subtitle C. State and local governments implement solid waste management guidelines under RCRA Subtitle D. EPA's authority under Subtitle D is limited; its primary role is to promulgate sanitary landfill criteria to prevent adverse effects on health or the environment. As of 2013, EPA has not finalized any solid waste management requirements specifically applicable to the disposal of Bevill waste.[430]

In situations where facilities combine tailings with mineral processing wastes that exhibit hazardous characteristics, these waste mixtures may also fall under RCRA Subtitle C. Red and brown muds from bauxite refining, however, are specifically excluded by the Bevill Amendment from regulation under RCRA Subtitle C. Finally, the MSHA specifies inspections and safety standards for impoundments, retention dams, and tailings ponds, and the FEMA is charged with administering a national dam safety program that includes surface impoundment structures.[431]

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[429] "Hazardous Substance Fact Sheet: Sodium Hydroxide," New Jersey Department of Health. Accessed November 12, 2015, at http://nj.gov/health/eoh/rtkweb/documents/fs/1706.pdf.

[430] L. Luther, "Background on and Implementation of the Bevill Bentsen Exclusions in the Resource Conservation and Recovery Act: EPA Authorities to Regulate 'Special Wastes,'" *Congressional Research Service* R43149 (Washington, DC: U.S. Government Printing Office, 2013).

[431] 30 CFR Part 57, Subpart S. For more information, see: "Dam Safety Standards and Technical Guidance," MSHA. U.S. Department of Labor. Accessed October 30, 2015, at: http://www.msha.gov/DamSafety/DamSafetyTechGuidance.asp.

Exhibit 1.H.2. Potential Releases Associated with the Bayer Process

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Fugitive Dust	The early stages of the Bayer process (crushing and grinding) may release dust.	The following practices help to manage fugitive dust[432]: • Application of water through wet spray systems • Enclosure of the dust source • Exhaust ventilation • Maintenance of a slight negative pressure for enclosed grinding equipment, which ensures that any air leakage will flow into and not out of the equipment.
Red Mud	Red mud is the waste material that is removed from the target metal during the Bayer process. [433] It contains iron, aluminum, silica, calcium and sodium, depending on the original ore used. Although red mud by itself is not toxic, it is extremely alkaline with a pH value between 13 and 14 and can cause environmental damage if leaching, spilling, or wind erosion occurs.	Red mud is generally stored on site in ponds and is not hazardous, although it can pose environmental and human health concerns if it leaches out of the containment pond or releases dust from dried mud lakes. Potential uses for red mud are limited, though the following options have been explored with some success: recovering raw materials from red mud, using red mud as an input in cement production, or using red mud to naturally purify water. [434]
Sodium Hydroxide	Sodium Hydroxide, or caustic soda, is a main input into the Bayer process that is generally recycled through the process. In some cases, generally due to human error, caustic soda is spilled and released into the environment.	Proper handling and storage of sodium hydroxide in proper containers should allow the fluid to be fully recycled.[435]

[432] Department of Health and Human Services, Center for Disease Control and Prevention, *Dust Control Handbook for Industrial Minerals Mining and Processing* (Washington, DC: U.S. Government Printing Office, 2012).

[433] "Primary Metals – Chapter 4: Aluminum Smelting and Refining," Illinois Sustainable Technology Center, University of Illinois. Accessed November 5, 2015, at http://www.istc.illinois.edu/info/library_docs/manuals/primmetals/chapter4.htm.

[434] Dong-Yan Liu and Chuan-Weng Wu, “Stockpiling and Comprehensive Utilization of Red Mud Research Progress," *Materials* (2012), p. 1232-1246.

[435] F.E. Farghly, M. A. Barakat, and S. M. El-Sheikh, "Removing Al and Regenerating Caustic Soda from the Spent Washing Liquor of Al Etching," *Journal of Materials* 57:8 (2005), p. 34-38.

Potential releases from aluminum and bauxite refining using the Bayer process are regulated under the ELGs outlined by the CWA for the nonferrous metals manufacturing point-source category.[436] These requirements limit the volume of process wastewater overflow that may be discharged from impoundments. Runoff from surface impoundments may be regulated under stormwater permits.[437] Stormwater permits regulate stormwater contaminated by contact with material from mining activities.

State Regulations

State and local governments implement solid waste management guidelines under RCRA Subtitle D. Currently, facilities using the Bayer process and releasing red and brown muds operate in Texas and Louisiana, and are regulated under those states' solid waste regulations (Texas: Title 30 Texas Administrative Code Chapter 335; Louisiana: Title 33, Part VI). Both states mandate operating and closure standards for surface impoundments holding processing waste.

Non-Operating Sites and Currently Operating Facilities

Non-Operating Sites

None of the non-operating mining and processing CERCLA sites within the sample reviewed used Bayer processing. Additional research identified the St. Croix alumina facility, located on the St. Croix Island of the U.S. Virgin Islands, and the North Alcoa Site, located in East St. Louis, as non-operating Superfund sites that produced alumina using the Bayer process. At these sites, on-site disposal of red and brown muds led to contamination in the surrounding area:

- **St. Croix Alumina** (EPA ID VIN000206465): The St. Croix Alumina (SCA) site produced alumina from bauxite using the Bayer process.[438] The site, which began operations in 1962,[439] generated red mud from the Bayer process.[440] The caustic sludge contaminated land in the area surrounding the facility and seeped into the Alucroix Channel, which feeds into the Caribbean Sea.[441]

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[436] 40 CFR Part 421.

[437] The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: Greater Yellowstone Coalition v. Lewis, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[438] "Former St. Croix Alumina (SCA) site in St. Croix VI," Integrated Solar and Wind Energy Powers Oil Recovery. Accessed November 13, 2015: https://frtr.gov/pdf/meetings/may10/presentations/gordon-presentation.pdf.

[439] Daniel Shea, "EPA Begins Superfund Evaluation of Red Mud," *Virgin Islands Daily News* (June 9, 2011). Accessed November 13, 2015: http://virginislandsdailynews.com/news/epa-begins-superfund-evaluation-of-red-mud-1.1159506.

[440] Fiona Stokes, "V.I. reaches $135M settlement with companies blamed for environmental damage on St. Croix's south shore," *Virgin Island Daily News* (June 14, 2014). Accessed November 18, 2015: http://virginislandsdailynews.com/news/v-i-reaches-135m-settlement-with-companies-blamed-for-environmental-damage-on-st-croix-s-south-shore-1.1702800.

[441] Kery Murakami, "Lockheed Martin Denies Liability For Toxic Leak Damages," *Law 360* (May 12, 2015). Accessed November 13, 2015: http://www.law360.com/articles/654891/lockheed-martin-denies-liability-for-toxic-leak-damages.

In 2012, the Virgin Islands Department of Planning and Natural Resources (DPNR) reached a settlement with past owners and operators of the site.[442] According to the settlement, operators and owners of the site, as well as their successors, would be responsible for all past and future response costs related to releases of hazardous substances at the site, including bauxite residue.[443] It also required implementing a Maintenance/Monitoring/Inspection Plan.[444] Additionally, it required that the Upper Cooling Pond, in which bauxite residue is contained, be covered and restricted.[445] The site and its owners/operators have been involved in additional litigation since the 2012 settlement.

- **North Alcoa Site** (EPA ID IDILSFN0508010)[446]: Alcoa Inc. conducted alumina and aluminum fluoride refining at the North Alcoa site, which occupies 400 acres in East St. Louis, from 1903 to 1957.[447] During World War II, red mud from the site was mixed with limestone and soda ash in rotary kilns to create "brown mud." Both brown mud and red mud were disposed of at the site, initially in a place called Pittsburgh Lake and later at residue disposal areas (RDAs).

Bauxite was released from the dike of RDA 1.[448, 449] In 1997, Illinois EPA found elevated levels of lead, arsenic, cadmium, and cyanide in sediment and surface water samples at the site.[450] In

[442] Past owners and operators included St. Croix Alumina, LLC, Alcoa World Alumina LLC, St. Croix Renaissance Group, LLLP, and Lockheed Martin Corporation (the successor to Martin Marietta Alumina and Harvey Alumina).

[443] District Court of the Virgin Islands, *Agreement and Consent Decree Regarding the Former Alumina Refinery Property, Anguilla Estate, St. Croix, U.S. Virgin Islands* (February 15, 2012). Accessed November 18, 2015: http://www.federal-litigation.com/SCRG-ConsentDecree.pdf.

[444] District Court of the Virgin Islands, *Agreement and Consent Decree Regarding the Former Alumina Refinery Property, Anguilla Estate, St. Croix, U.S. Virgin Islands* (February 15, 2012). Accessed November 18, 2015: http://www.federal-litigation.com/SCRG-ConsentDecree.pdf.

[445] District Court of the Virgin Islands, *Agreement and Consent Decree Regarding the Former Alumina Refinery Property, Anguilla Estate, St. Croix, U.S. Virgin Islands* (February 15, 2012). Accessed November 18, 2015: http://www.federal-litigation.com/SCRG-ConsentDecree.pdf.

[446] "Region 5 Cleanup Sites, North Alcoa Site, Operable Unit 1," U.S. Environmental Protection Agency. Accessed November 17, 2015: http://www3.epa.gov/region5/cleanup/northalcoa.

[447] "Operable Unit 1, North Alcoa (Alcoa Properties) Site, Saint Clair County, East St. Louis, Illinois," U.S. Environmental Protection Agency. Accessed November 18, 2015: http://www3.epa.gov/region5/cleanup/northalcoa/pdfs/na-rod-2012.pdf.

[448] "Operable Unit 1, North Alcoa (Alcoa Properties) Site, Saint Clair County, East St. Louis, Illinois," U.S. Environmental Protection Agency. Accessed November 18, 2015: http://www3.epa.gov/region5/cleanup/northalcoa/pdfs/na-rod-2012.pdf.

[449] This on-site release is believed to have occurred in the 1930s.

[450] "Operable Unit 1, North Alcoa (Alcoa Properties) Site, Saint Clair County, East St. Louis, Illinois," U.S. Environmental Protection Agency. Accessed November 18, 2015: http://www3.epa.gov/region5/cleanup/northalcoa/pdfs/na-rod-2012.pdf.

1999, EPA found elevated levels of lead in the red mud ponds onsite.[451] Alcoa began reclamation of soil at the site in 2014.[452]

Currently Operating Facilities

Two of the currently operating facilities reviewed, Noranda Gramercy (MSHA ID 1600352) and Sherwin Alumina (MSHA ID 4100906), produce alumina and conduct Bayer processing. Evidence from publicly available sources revealed that spills of process chemicals (including sodium hydroxide) can be a concern at currently operating facilities:

- **Noranda Gramercy** (MSHA ID 1600352): Noranda Alumina LLC has operated the Gramercy, Louisiana facility since 2004.[453] The original operator, Kaiser Aluminum & Chemical Corporation, began in 1959.[454] The facility uses the Bayer process to chemically refine and convert bauxite into alumina, of which it produces 1.2 million metric tonnes per year. The facility has 32 releases recorded in ERNS. The releases, which took place between 1992 and 2011, included lead compounds, sulfuric acid, sodium hydroxide, hydrochloric acid, 2,4-dimethylphenyl, carbon disulfide, asbestos, and chlorine. The largest releases took place in 2000 and 2005, when 30,000 and 44,000 gallons of sodium hydroxide were released due to a pipe break and operator error, respectively. These releases were likely related to Bayer processing as sodium hydroxide is used in the Bayer process.

  The site contains red mud in sludge ponds, which cover approximately 920 acres.[455] These sealed ponds feature steep walls to provide stability.[456] Additionally, the ponds are dewatered to stabilize the red mud.[457]

- **Sherwin Aluminum** (MSHA ID 4100906): The Sherwin Alumina facility in Gregory, Texas has the capacity to produce 1.65 million tonnes of alumina from bauxite annually.[458] This facility has two reported releases in ERNS. These releases occurred in

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[451] "Operable Unit 1, North Alcoa (Alcoa Properties) Site, Saint Clair County, East St. Louis, Illinois," U.S. Environmental Protection Agency. Accessed November 18, 2015: http://www3.epa.gov/region5/cleanup/northalcoa/pdfs/na-rod-2012.pdf.

[452] "Region 5 Cleanup Sites, North Alcoa Site, Operable Unit 1," U.S. Environmental Protection Agency. Accessed November 17, 2015: http://www3.epa.gov/region5/cleanup/northalcoa.

[453] "Mine Data Retrieval System," U.S. Department of Labor. Mine Safety and Health Administration (MSHA). Accessed November 11, 2015: http://arlweb.msha.gov/drs/drshome.htm.

[454] "Alumina Refinery – Gramercy, Louisiana," Noranda. Accessed November 11, 2015: http://www.norandaaluminum.com/gramercy-alumina.php.

[455] "DEQ Fact Sheet: Alumina Plant Facts," Louisiana Department of Environmental Quality. Accessed November 18, 2015: http://www.deq.louisiana.gov/portal/portals/0/news/pdf/Aluminaplantfacts.pdf.

[456] "DEQ Fact Sheet: Alumina Plant Facts," Louisiana Department of Environmental Quality. Accessed November 18, 2015: http://www.deq.louisiana.gov/portal/portals/0/news/pdf/Aluminaplantfacts.pdf.

[457] "DEQ Fact Sheet: Alumina Plant Facts," Louisiana Department of Environmental Quality. Accessed November 18, 2015: http://www.deq.louisiana.gov/portal/portals/0/news/pdf/Aluminaplantfacts.pdf.

[458] "About Us," Sherwin Alumina Company, LLC. Accessed November 11, 2015: http://www.sherwinalumina.com/page.php?name=about-us.

> 2001 and 2007, and consisted of 15,013 and 2,783 pounds of sodium hydroxide released due to equipment failure. This site also received complaints about dust emitted from the red mud lagoons, which are used as a waste management method.[459] A Texas Department of State Health Services Health Consultation concluded that, although several metals exceeded health based screening values, the exposure of metal contaminants in the red mud dust does not pose a public health hazard.[460]

Because of the small sample size, it is difficult to determine the extent or trend of releases related to Bayer processing. Based on these cases, however, the primary concern at currently operating facilities appears to be releases of sodium hydroxide, which is extremely corrosive and can cause severe burns and permanent tissue damage as well as increases in the pH of surface water that it contaminates.[461] Additionally, proper waste management of red mud is essential for preventing contamination. Information about currently operating sites, however, does not consider future long-term waste management issues.

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[459] Texas Department of State Health Services, *Letter Health Consultation: Evaluation of Air Quality, Leo Miller Road Site* (Washington, DC: U.S. Government Printing Office, 2009); accessed November 12, 2015, at: http://www.atsdr.cdc.gov/HAC/pha/LeoMillerRoadSite/LeoMillerRdLetterHC05-15-2009.pdf.

[460] Texas Department of State Health Services, *Letter Health Consultation: Evaluation of Air Quality, Leo Miller Road Site* (Washington, DC: U.S. Government Printing Office, 2009); accessed November 12, 2015, at: http://www.atsdr.cdc.gov/HAC/pha/LeoMillerRoadSite/LeoMillerRdLetterHC05-15-2009.pdf.

[461] "Hazardous Substance Fact Sheet: Sodium Hydroxide," New Jersey Department of Health. Accessed November 12, 2015, at http://nj.gov/health/eoh/rtkweb/documents/fs/1706.pdf.

Section 2: Waste Management Practices

A. Mine-Influenced Water

B. Waste Rock Management

C. Tailings Management

D. Leaks and Spills Resulting in Releases from Mining and Associated Processes

A. Mine-Influenced Water (MIW)

Background

MIW encompasses any water whose chemical composition has been affected by mining or mineral processing. The most prevalent type of MIW is AMD, but MIW also includes drainage that is neutral or alkaline. In addition to environmental concerns posed by acidity or alkalinity, MIW often contains elevated concentrations of mobilized contaminants, suspended solids, or sulfate or arsenate content.

There are many potential sources of MIW, as it includes any natural waters that come into contact with mining operations. Common sources include groundwater affected by pits or underground workings, surface water that has entered surface excavations, or any precipitation that comes into contact with pit faces, leach piles, waste rock piles, or tailings piles. MIW does not include purposeful discharges of mining or milling wastes into surface waters.[462]

Since the very beginning of mining history, MIW has been a source of both environmental and human health concerns. References to specific reactive sulfides and their degradation to acid were made as early as the Roman era, and by the mid-16th century, the harmful effects on water and soil were well known.[463] MIW can create long-lasting effects that far outlive the active lifespan of a mine. As a result, many non-operating sites continue to cause environmental damage even after centuries of inactivity. MIW remains one of the most significant issues across the mining industry; acid drainage affects thousands of miles of streams and rivers in the U.S., an estimate that does not consider its effects on groundwater.[464]

Potential Risks

Environmental issues resulting from MIW vary depending on commodity, climate, type of mine or processing facility, and mine phase. A key characteristic for most MIW (whether acidic, neutral, or alkaline drainage) is an elevated concentration of trace elements that have leached from surrounding solids such as waste rock, tailings, or mine surfaces. These contaminants, usually found in an insoluble sulfide phase, are released to solution through an oxidation reaction. In AMD, the drainage contains sulfidic minerals that react with oxygen and water to

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[462] R.L. Schmiermund and M.A. Drozd, "Acid mine drainage and other mining influenced waters (MIW)," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p.599-617.

[463] The International Network for Acid Prevention, Global Acid Rock Drainage Guide (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), Chapter 2.

[464] U.S. Environmental Protection Agency, Office of Compliance, *Sector Notebook Project: Profile of the Metal Mining Industry* (Washington, DC: U.S. Government Publishing Office, 1995).

release acid to the solution, lowering its pH.[465] AMD can also increase concentrations for other contaminants, as low-pH conditions further mobilize any contaminants in surrounding materials. The solution, now with elevated contaminant content and/or a low pH, poses risks to surrounding groundwater, surface water, air, soil, and sediments.

Multiple chemical, physical and biological factors control the rate at which these reactions occur, and thus the severity of MIW's effects. For example, waste rock with a fine grain size generally oxidizes much more rapidly because of its increased surface area, causing more metals or acid to be released to solution. Temperature, ambient pH, and microbial activity also have significant effects on the composition of mine waters. These factors affect the transport and resulting drainage of MIW. In hot and arid climates, for example, less water is generally available for transport, and discharges are thus less likely to travel to the receiving environment.[466] Geological factors also play a key role. Sulfidic minerals such as pyrite are acid-generating, thus increasing the potential for acid-mine drainage and mobilized contaminants; other minerals such as calcite and lime are acid-consuming and produce neutral or alkaline waters.[467] Media rock with high concentrations of zinc, copper, lead, cobalt, nickel, and iron are more likely to generate AMD.[468] Mitigation efforts must take these differences into account to counter the negative effects of MIW on each site.

Prevention and Mitigation Techniques

Efforts to prevent and control MIW were minimal until contemporary mining. Finding effective techniques for mitigation and prevention of MIW remains a challenge. In the past, mine operators did not often attempt to mitigate or prevent mine-influenced water. Even with the development of contemporary mining mitigation techniques, operators struggle to find effective strategies. Nearly all types of mining operations create MIW, and prevention and mitigation efforts must be tailored to the specific characteristics and quantities of drainage present at the site.

MIW prevention strategies follow three general courses of action: the reduction of exposed mine features (e.g., open pits, waste rock piles), the removal of acid-generating or otherwise harmful geochemical characteristics from mine waste, and the diversion of run-off away from mine features. The application of covers to waste rock piles and tailings storage facilities and the

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[465] R.L. Schmiermund and M.A. Drozd, "Acid mine drainage and other mining influenced waters (MIW)," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p.599-617.

[466] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), Chapter 2.

[467] Thomas Nash, *Overview of Mine Drainage Geochemistry at Historical Mines, Humboldt River Basin and Adjacent Mining Areas* USGS Bulletin 2210-E (Washington, DC: U.S. Government Printing Office, 2003). Accessed December 13, 2015, at http://pubs.usgs.gov/bul/b2210-e/B2210E508V6.pdf.

[468] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), Chapter 2.

practice of backfilling open pits or underground adits minimizes the ability of oxygen or water to pass through those features. Operators can segregate and selectively deposit solid waste – tailings or waste rock – with high concentrations of sulfidic material. Diversion channels and ditches prevent MIW by intercepting and conveying runoff before it reaches mining sites. Under proper geologic conditions, burying waste rock or using overburden material as backfill can also reduce acid generation substantially.[469] Even with the application of the above strategies, however, ongoing monitoring must be conducted to assess the efficacy of any prevention methods at a given mine site if they fail or prove insufficient.

The effects of MIW are often widespread and long-lasting. Most mines require ongoing management for acidic drainage, as it continues to be a problem even at sites that have been inactive for more than a century. Current mitigation methods for MIW take place before and after mine-water releases.[470]

Two general types of treatment methods exist when prevention is not sufficient: active and passive. Both types work to remove or reduce the concentration of contaminants in MIW, and usually require long-term funding and maintenance. Active treatments generally require ongoing human intervention, operation, and infrastructure, usually through the construction of a treatment plant. On the other hand, passive methods typically employ natural construction materials and involve the creation of a self-sustaining treatment system, such as wetland/ecosystem habitats.[471]

Both passive and active treatments use the same basic methods to mitigate the contaminants in MIW: aeration, chemical addition, and removal. For example, passive treatments achieve mitigation by constructing wetlands to facilitate aeration and to foster microbes that consume contaminants. Alternatively, they can build of a drain or bed that neutralizes pH levels in MIW before the MIW enters the local environment. Active methods involve capturing MIW and using treatment circuits to remove contaminants, such as ion exchange or chemical precipitation, or add counteracting chemicals to the MIW, as with alkaline addition for AMD.[472] A variety of treatment techniques are available, but each site is unique and the best mitigation techniques for any facility will vary depending on the commodity, scale, processing methods, climate, and site characteristics.

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[469] The International Network for Acid Prevention, Global Acid Rock Drainage Guide (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), Chapter 6.

[470] G. Hilson and B. Murck, "Progress toward pollution prevention and waste minimization in the North American gold mining industry," *Journal of Cleaner Production* 9 (2001), p. 405-415.

[471] The International Network for Acid Prevention, Global Acid Rock Drainage Guide (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), Chapter 7.

[472] The International Network for Acid Prevention, Global Acid Rock Drainage Guide (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), Chapter 7.

B. Waste Rock Management

Introduction

Waste rock is uneconomic material that abuts or surrounds commodity-bearing ore and is currently deemed not fit for processing. The commodity is separated from waste rock at the mine site, at which point the operator disposes of the waste rock. Disposal typically involves depositing the waste rock in dedicated dumps or piles,[473] or in some cases using it as mine backfill. Waste rock can also be co-disposed with paste or filtered tailings, or in a slurry pond.[474] Waste rock containing residual quantities of a commodity may later become economical because more efficient processes have been developed, allowing operators to treat the waste as ore using low-cost methods such as acid leaching or, depending on the mineralogy of the rock, milling. To this end, operators sometimes reserve waste rock that contains marginally economic grades of ore, either to mill when doing so is economical or to mix with high-grade ore to maintain the grade of feed to the mill.

Historically, operators often disposed of waste rock in the local environment without attempting to contain the waste (e.g., by depositing it in or near flowing surface water). In contrast, current operations are subject to a regulatory framework that addresses waste disposal before the start of mining and processing activity, sets performance and monitoring standards, and requires an approved reclamation plan. As a result, management practices have improved, but releases of hazardous substances continue. Further, releases from waste rock disposals can arise years after operations have ceased, through discharges of MIW, and pile deformation or collapse. Thus, waste rock disposals are often the focus of reclamation and closure plans and require consistent and long-term maintenance, monitoring, and potentially treatment.

Past and Current Use

In the past, miners deposited waste materials from mining operations in the most convenient available area without attempting to limit the waste materials' impact on the local environment. Over time, operators increasingly considered the environmental impact of waste rock dumping methods by developing dedicated dump and pile areas that featured topographical or constructed

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[473] This paper uses both "dump" and "pile" to reflect the fact that mine operators may dispose of waste rock by dumping it over the side of slope or by using conveyors to pile the rock on flat ground. Although the paper uses both terms for the sake of comprehensiveness, it does not consider differences between the two or specificities of one or the other regarding the technicalities of construction and maintenance or the potential for release.

[474] "Waste rock" is the most common term for the material extracted alongside a commodity and separated from the commodity at the mine site. Alternative terms include "production rock," "excess rock," and "barren rock." Sometimes, waste rock is grouped into the category of "overburden." Some operators reject the term waste rock because some states tax material defined as "waste" on a per tonnage basis. For the purposes of this paper, the term "waste rock" is used as it is defined above. This document will not use any other term to refer to what the document has defined as "waste rock" unless a specific non-operating site or current facility uses that term. For terms and reason for variations, see D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection, in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 412.

barriers to contain waste rock. Miners also backfilled surface and underground mines with waste rock more frequently, which limited a site's topographical and environmental footprint. Over the past twenty years, particular progress has been made in understanding and minimizing the impact of MIW (including AMD),[475] an environmental hazard associated with waste rock piles and dumps.[476]

Because of rising metal prices and technological innovations that reduced the cost of extracting ore, the contemporary mining industry has moved towards larger operations that exploit economies of scale. Together, those trends have made the mining and processing of low-grade ore increasingly economical. Increased production and the extraction of low-grade ore have resulted in a concurrent increase in the amount of waste material produced at mines.[477] Thus, while contemporary operators are more cognizant of the impact waste rock deposition has on the environment and can better manage AMD, they are also producing greater volumes of waste rock.

Technical Description

Waste rock consists largely of coarse material – cobbles, rocks, and boulders – in addition to some fine particles.[478] Although waste rock encompasses material of many different sizes, typically most particles are greater than 20 centimeters in diameter. Because of that variation, waste rock stratifies itself by size when it is dumped down an incline, with the coarsest fraction landing at the bottom. Waste rock is also heterogeneous in terms of geochemical composition, mineralogy and hydrology, which cause significant environmental diversity within individual waste rock piles or dumps themselves.[479]

Underground and surface mining operations both produce waste rock, although surface mines yield a far greater proportion compared to the amount of ore extracted.[480] Ore and waste are extracted separately, and the waste rock is transported to the disposal site, which may be in a

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[475] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 1.2.

[476] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 3.

[477] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 1. Accessed November 21, 2015, at: http://www3.epa.gov/epawaste/nonhaz/industrial/special/mining/techdocs/tailings.pdf; and National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[478] Marc Orman, Rich Peevers, and Kristin Sample, "Chapter 8.11: Waste Piles and Dumps," in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 672.

[479] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 3.

[480] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 412.

previously mined pit or at a dedicated dump or pile. Once there, trucks end-dump the waste rock over the side of the dump lift. Alternatively, conveyors may be used to stack the waste rock on top of the pile.[481] Depending on the topography of the mine site, waste rock dump and pile sites vary in design and the degree to which the operator must amend the local topography.[482] In most cases, the unit will have stormwater runoff collection ponds to control sediment that the pile emits during precipitation, and surface runoff diversion ditches to prevent natural runoff from entering the waste rock storage unit.[483]

Both dumping and stacking create an angle of repose slope in the waste rock. Typically, the slope is about 35 to 40 degrees, or has a horizontal length to vertical height ratio of about 2:1 to 3:1.[484] The material is contained on the low-end of the pile or dump by a constructed toe to increase stability and limit seepage from the facility. Operators typically can install lifts and benches to minimize the height from which material falls when dumped, and grade the slope to ensure a proper angle and protect the exposed dump face from runoff.[485] Unlike tailings storage facilities or heap and dump leach pads, waste rock piles or dump sites are rarely lined, although reclamation plans sometimes call for post-closure coverage to mitigate the potential for weathering and subsequent dissolution of soluble materials.[486]

Potential Sources of Hazardous Substances

The risk for contamination from hazardous substances originating in waste rock depends on the mineralogy and geochemical composition of the waste rock and its level of exposure to air and water at the disposal site. For example, sulfide rock can generate acids that dissolve trace elements that, without long-term containment, collection, and treatment, pose a significant concern long after initial disposal. Discharges can take years to develop, and pose a long-term risk of hazardous releases at the site. Thus, operators must conduct mitigation efforts including

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[481] Dirk Van Zyl, "Mine waste disposal," in *Geotechnical Practice for Waste Disposal*, ed. D.E. Daniel (Medford, MA: Springer Science and Business Media, 2012), p. 271-272.

[482] Marc Orman, Rich Peevers, and Kristin Sample, "Chapter 8.11: Waste Piles and Dumps," in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 668 and 672.

[483] Dirk Van Zyl, "Mine waste disposal," in *Geotechnical Practice for Waste Disposal*, ed. D.E. Daniel (Medford, MA: Springer Science and Business Media, 2012), p. 271.

[484] Marc Orman, Rich Peevers, and Kristin Sample, "Chapter 8.11: Waste Piles and Dumps," in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 672 and 676.

[485] Dirk Van Zyl, "Mine waste disposal," in *Geotechnical Practice for Waste Disposal*, ed. D.E. Daniel (Medford, MA: Springer Science and Business Media, 2012), p. 272.

[486] See Marc Orman, Rich Peevers, and Kristin Sample, "Chapter 8.11: Waste Piles and Dumps," in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 676-677.

maintenance, monitoring and – if the site is potentially acid generating - treatment.[487] To minimize the risk of waste rock piles or dumps causing environmental harm from deformation or collapse, dedicated visual and mechanical monitoring is often sufficient.[488]

State and Federal Regulations

Since 1980, federal and state governments have constructed a system of regulatory restrictions and permitting requirements to govern mine waste disposal that apply to waste rock piles and dumps.[489] At both the federal and state level, land management and environmental regulations address potential environmental risks from waste rock disposal and management.

Mining and processing operations may be subject to preliminary environmental planning and assessment, operational requirements and performance standards, and reclamation requirements.

Federal Regulations

Federal agencies have promulgated rules regarding tailings management. These include:

- **Solid waste.** RCRA Section 3001(b)(1) (the Bevill Amendment) exempts solid waste from extraction, including waste rock, from regulation as hazardous waste under RCRA Subtitle C. State and local governments implement solid waste management guidelines under RCRA Subtitle D. EPA's authority under Subtitle D is limited; its primary role is to promulgate sanitary landfill criteria to prevent adverse effects on health or the environment. As of 2013, EPA has not finalized any solid waste management requirements specifically applicable to the disposal of Bevill waste.[490]

[487] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 451.

[488] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 463.

[489] Marc Orman, Rich Peevers, and Kristin Sample, "Chapter 8.11: Waste Piles and Dumps," in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 667.

[490] L. Luther, "Background on and Implementation of the Bevill Bentsen Exclusions in the Resource Conservation and Recovery Act: EPA Authorities to Regulate 'Special Wastes,'" *Congressional Research Service* R43149 (Washington, DC: U.S. Government Printing Office, 2013).

Exhibit 2.B.1. Potential Releases Associated with Waste Rock

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Deformation or Collapse	Waste rock piles can reach heights of up to five hundred meters. Those structures can fail for a variety of reasons, either due to significant precipitation, erosion, seismic activity, or fundamental structural instability. When failure occurs, waste rock escapes the bounds of the facility and any hazardous substances present in the waste rock can enter the local environment. Furthermore, even geochemically benign waste rock ejected from a waste rock pile as a result of sudden failure can cause significant physical harm to the local environment.[491]	Pre-operational planning and analysis to account for and avoid topographical and geological factors that could contribute to failure mitigates the possibility of release in the operational and post-closure phases.[492] Simple monitoring and visual inspection, if performed consistently and thoroughly, is essential to lessen the risk of deformation or collapse.[493] Additionally, an automated wireline extensometer can monitor the physical stability of a dump or pile remotely by recording the changes in tension of a line anchored in the waste rock.[494] Foundation pore water pressure analysis and foundation strains are more sophisticated mitigation methods.[495] The construction of dumps as a series of wrap-arounds so as to form a flat face minimizes the slope-related failure potential and facilitates reclamation.[496]

[491] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 463.

[492] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1 ("*GARD Guide*").

[493] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 463.

[494] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 452.

[495] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 463.

[496] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 462.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
MIW/AMD	Rock drainage can occur with a wide variety of mineralogical, hydrological, and chemical factors in place, although there are multiple standard test procedures used to predict the character of waste rock.[497] MIW generally may contain residual process chemicals or mobilized contaminants, with high acidity further mobilizing potentially hazardous trace elements. AMD involves the oxidation of metal sulfide minerals, often in the host rock of metal mining commodities. Extraction exposes the rock to air and water thus increasing its acid-generating potential. Upon exposure, a number of factors determine the rate, severity, and mobility of acid generation: the kind of sulfide mineral present, amount of water exposure, amount of oxygen exposure, presence of ferric iron, bacteria to catalyze oxidation reaction, and generated heat.[498] The sizes of waste rocks in a pile or dump can vary, from fine particles to boulders. Although a part of a waste rock pile predominantly made up of large rocks has increased air flow and lower permeability, smaller particles generate more acid because more of their surface area is exposed to oxygen, which leads to increased oxidization of constituent sulfides.[499] AMD has a considerable lag time from the first deposition of waste material to the observation of acidic discharge, making it an ongoing and potentially perpetual source of hazardous contamination at a mine site.[500]	Pre-operational analysis of the acid generating potential of waste rock is essential to determine whether the operation is feasible or how to neutralize any acid produced.[501] Potentially acid-generating waste rock may be saturated during disposal, or co-disposed with tailings and/or overburden to neutralize acidity. Co-disposal restricts access to oxygen of potentially acid generating material. Co-disposal material may also be alkaline-generating, thereby neutralizing acid-generating potential of waste rock. Co-disposal may involve the dumping of reactive waste rock into a saturated tailings impoundment or introducing waste rock to tailings before they undergo the filtration process to become paste tailings, creating "paste rock."[502] Co-disposal can also involve the layering of potentially acid generating layers with neutralizing layers (or vice versa) to minimize the transportation of acidic or basic discharge.[503] Potentially acid or alkaline generating waste rock piles or dumps may also be encapsulated by non-acid generating or neutralizing materials to act as a physical and chemical barrier to prevent rock drainage. Consideration of the hydrology and topography of the dump or pile site is necessary for effective encapsulation.[504]

[497] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 1.

[498] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 4-6.

[499] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 451.

[500] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 2.

[501] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 9-10; The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 5.0.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Erosion	Many factors can contribute to the erosion of the waste rock dump site. Most commonly, erosion is caused by hydrological weathering from precipitation and runoff or the geochemical nature of the waste rock material itself. Erosion can result in sudden deformation and collapse and/or the release of hazardous material into the environment.[505]	The operator must characterize the erosion potential of waste rock material before the start of operations to determine the optimal manner of deposition. A concave pile design mimics the natural path of erosion and mitigates the impact of an erosive event. Material with low erosion potential can cap higher erosion potential material.[506] That cap can be applied continuously as the disposal is constructed. To prevent water from entering the waste rock disposal and contributing to erosion, an operator can dig ditches around the disposal to divert water.[507] Consistent slope and water monitoring are also necessary to prevent erosion, with the potential addition of water treatment depending on the chemical content of the water.[508]

502 International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.7.

503 U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 7.

504 International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.5.

505 Marc Orman, Rich Peevers, and Kristin Sample, “Chapter 8.11: Waste Piles and Dumps,” in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 675-676.

506 Marc Orman, Rich Peevers, and Kristin Sample, “Chapter 8.11: Waste Piles and Dumps,” in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 675-676.

507 Dirk Van Zyl, “Mine waste disposal,” in *Geotechnical Practice for Waste Disposal*, ed. D.E. Daniel (Medford, MA: Springer Science and Business Media, 2012), p. 271.

508 Marc Orman, Rich Peevers, and Kristin Sample, “Chapter 8.11: Waste Piles and Dumps,” in *SME Mining Engineering Handbook*, ed. Peter Darling (Englewood, CO: Society for Mining, Metallurgy, and Exploration, Inc., 2011), Volume 1, p. 675-676.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Topographical Impacts	Waste rock piles can reach heights of up to five hundred meters, potentially altering the topography and landscape of the mine area significantly.[509]	At closure, backfilling open-pit mines, in-pit co-disposal of tailings and waste rock with dry or wet covers,[510] and revegetation of the mining area can lessen or minimize topographical impacts.[511]

[509] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 463.

[510] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.7.

[511] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.6.

Facilities sometimes dispose of Bevill-exempt wastes in the same waste management units as non-exempt hazardous wastes, however.[512] In situations where facilities combine tailings with other wastes that exhibit hazardous characteristics, the waste mixtures may fall under RCRA Subtitle C regulations.

- **Water.** To comply with water quality standards under the CWA, mine operators must obtain permits under NPDES for any discharge of pollutant from a point source to waters of the United States.[513] For many hardrock commodities, EPA has promulgated ELGs requiring technology-based controls and establishing specific water quality standards for mine drainage from waste rock dumps.[514] The CWA sets effluent limits based both on the use of the best practicable control technology and those possible with the use of available and economically achievable technologies. Title III also sets a separate set of standards for new facilities.[515] For discharges or pollutants not covered by the ELGs, EPA or the delegated state authority incorporates limits into permits on a site-specific basis. The NPDES program applies to both active and inactive mines, as well as abandoned mines where legally responsible owners or operators of point sources can be identified.

  Runoff from waste rock piles or dumps may be regulated under NPDES stormwater permits.[516] Stormwater permits regulate stormwater contaminated by contact with material from mining activities, primarily requiring site-specific pollution prevention planning and/or implementation of mitigation practices.[517] These include treatment requirements, operating procedures, practices to control runoff, and monitoring.

  While EPA issues and oversees point-source discharge permitting under Section 402 of the CWA, the USACE issues "dredge and fill" permits under Section 404 of the CWA. Under CWA Section 404, mining operations may need to obtain a permit from USACE

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[512] An EPA survey of 106 facilities in 1989 indicated that 20 facilities placed mixtures of Bevill-exempt and non-exempt wastes in the same waste management unit. See: U.S. Environmental Protection Agency, *Mineral Processing Facilities Placing Mixtures of Exempt and Non-Exempt Wastes in On-site Waste Management Units: Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 2013).

[513] Point sources are defined broadly; they include any discernable, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, or container. "Waters of the United States" includes navigable waters, tributaries, interstate waters, intrastate waters used by interstate travelers, or for industrial purposes by industries engaged in interstate commerce. Generally, mining operations would fall under the Clean Water Act for process wastewater, mine drainage, and stormwater. 40 CFR 440 defines "mine drainage" as water drained, pumped, or siphoned from active mining areas, including rock dumps. See: U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003).

[514] For example: 40 CFR 436 (mineral mining and processing); 40 CFR 440 (ore mining and dressing); 40 CFR Part 421 (nonferrous metals manufacturing).

[515] See 40 CFR 36 and 40 CFR 40.

[516] Seepage to groundwater is not considered a point source, and is not regulated under the Clean Water Act. The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[517] Best management practices for stormwater permits are described at 40 CFR 122.2.

to address the discharge of dredged or fill materials into surface water, including wetlands. In areas with streams, wetlands or lakes, construction and ongoing modifications of waste rock piles or dumps can trigger this requirement. Some regulatory uncertainty exists regarding how mining overburden, slurry, and tailings are regulated under the CWA, because different definitions of fill material are used by EPA and USACE. Thus, Section 404 permits have been issued for mining operations outside of NPDES permitting requirements.[518]

Mining operations on public federal land are subject to additional regulation. The BLM Section 3809 rules require operators to supply operational and baseline environmental information to the BLM to analyze potential environmental impacts and prevent undue degradation. That information includes an assessment of the facility's potential to generate acid drainage or other leachate. If possible, operators must further identify and pre-treat any potentially acid-generating or otherwise deleterious material prior to generation. If not, operators must prevent the migration of deleterious drainage, including capture and treatment and other engineering designs for the waste rock depository. If a facility has significant potential for acid drainage, the BLM will inspect it four times per year.[519]

State Regulations

Many states have operational, technology, and performance-based standards for general mining waste management and disposal in state solid waste regulations, state groundwater pollution laws, dam safety programs, or state mining laws. Generally, state and local governments implement solid waste management guidelines under RCRA Subtitle D, establishing operating and closure requirements that apply to all types of industrial waste disposal units. States with delegated authority also implement CWA regulations, with state programs at least as stringent as federal regulations. Many state mining programs address mine drainage. For example:

- **Alaska's** land reclamation performance standards require that operators reclaim any mined areas that have the potential to generate acid.[520]
- **California's** water quality program classifies mine waste based on potential threat to water quality. Waste rock with elevated levels of potentially deleterious substances must be placed in an engineered containment facility, and monitoring must be conducted to properly distinguish between waste rock types that pose more or less environmental impact.[521]

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[518] C. Copeland, "Controversies over Redefining 'Fill Material' Under the Clean Water Act," *Congressional Research Service* RL31411 (Washington, DC: U.S. Government Printing Office, 2013).

[519] U.S. Department of the Interior, Bureau of Land Management, *Surface Management Handbook* H-3809-1 (Washington, DC: U.S. Government Printing Office, 2012), Section 5.3.2.

[520] AS 27.19.020; 11 AAC 97.200-240.

[521] California Code of Regulations, Title 27, Section 22480.

- **Tennessee's** Water Quality Standards deem unusable any groundwater areas in which AMD occurs.[522]

Many states, however, exclude waste rock that has not been chemically treated from certain environmental regulatory programs.

Non-Operating Sites and Currently Operating Facilities

Many of the sites reviewed below began operations before the promulgation of major environmental laws in 1980. Since then, however, mine sites have continued to experience releases from waste rock. Piles and dumps can reach hundreds of meters high and, without consistent monitoring, pose a significant risk of deformation or collapse. Waste rock itself may contain mineral contaminants inherent to the ore strata, may generate acid when constituent metal sulfide minerals are oxidized, or may discharge MIW bearing other hazardous material. In any of the above cases, erosion, seepage, and run-off from precipitation can discharge those contaminants into the local environment, and all remain viable release vectors at currently operating mine sites.

Additionally, exploitation of economies of scale has led to mining of lower grade ore in increasing quantities and frequency, which in turn generates larger volumes of waste rock as the operators work ore deposits of increasing size.[523] Current operators must manage the increased quantities of waste rock attendant to contemporary mining practices; an escalation in waste rock generation and rate of disposal has put stress on the structural integrity of existing pile and dump sites, leading to failure.[524]

Furthermore, there is often a significant lag time between the start of mine operations and waste rock deposition and the observation of AMD.[525] It may take at least five years for the oxidization of the acid-generating material and subsequent transportation into the local environment to begin.[526]

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[522] Tennessee Water Quality Standards, Rule 0400-40-02.

[523] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 1; and National Academy of Sciences, Committee on Technologies for the Mining Industry, Committee on Earth Resources, and National Research Council, *Evolutionary and Revolutionary Technologies for the Mining Industry* (Washington, DC: National Academy of Sciences, 2002).

[524] D.J.A. Van Zyl and J.N. Johnson, "Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 444.

[525] U.S. Environmental Protection Agency, *Technical Report: Acid Mine Drainage Prediction* (Washington, DC: U.S. Government Printing Office, 1994), p. 2.

[526] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 8.3.4.

In the below sample, documents confirmed at least eighteen non-operating sites or currently operating facilities experienced waste rock-related releases after 1980, out of a total of 105 sites reviewed.[527] Of those eighteen sites or facilities, ten experienced waste rock-related releases as a result of contemporary operations.

This review of contemporary mines did not capture information characterizing the scope and efficacy of reclamation and closure practices. Improper and failed reclamation have been the basis for past CERCLA actions at hardrock mines, and remains a consideration for the environmental performance of currently operating mines.

Non-Operating Sites

Documents confirmed that 19 of the 29 non-operating mining and processing CERCLA sites sampled for this review generated waste rock.[528] Of those 19 sites, waste rock was responsible for releases at 13 of the sites. Activity at many of the sites extended back before the widespread adoption of waste rock disposal practices, such as acid-generation predictive analysis and slope stability monitoring. Releases at those non-operating sites continued into contemporary mining period, however, due to AMD and other seeps into the local environment. For example:

- The **Captain Jack Mill** (EPA ID COD981551427) is a Superfund site in Ward, Colorado, that incorporates the Big Five Mine, the White Raven Mine, and the Captain Jack Mill Works. Gold and silver mining activity at the site began in 1861 and continued intermittently through 1992. The EPA placed the site on the NPL in 2003 following the detection of antimony, arsenic, cadmium, copper, lead, manganese, thallium, and zinc in nearby Left Hand Creek. The primary source of contamination was AMD from the Big Five adit, which originated in the 19th century. The site includes a waste rock pile that contributed to drainage because it prevented water from flowing from the adit, facilitating

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[527] The sample considered above includes phosphate mines and processing facilities. The process of extracting phosphate ore from its surrounding material produces a large amount of clay in Gulf Coast phosphate operations and rock in other regions of the United States. Phosphate rock mining wastes are included among the categories of exempt special wastes from RCRA Subtitle C regulations, the 1980 Solid Waste Disposal Act Amendments, and the EPA Report to Congress on Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale. See U.S. Environmental Protection Agency Region 10, *Record of Decision: Declaration, Decision Summary, and Responsiveness Summary for Eastern Michaud Flats Superfund Site* (Washington, DC: U.S. Government Printing Office, 1998). See 42 U.S.C. 6901–6992k, Sec. 3001(b)3)A)(i-iii); and U.S. Environmental Protection Agency, *Report to Congress: Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale* EPA530-SW-85-033 (Washington, DC: U.S. Government Printing Office, 1985).

[528] Silver Mountain Mine (EPA ID WAD980722789), Midnite Mine (EPA ID WAD980978753), Cyprus Tohono Mine (EPA ID AZD094524097), Pioneer Pit and Gardner's Point Placer Mine (EPA ID CAN000905978), California Gulch (EPA ID COD980717938), Captain Jack Mill (EPA ID COD981551427), Summitville Mine (EPA ID COD983778432), Bueno Mine and Mill Site (EPA ID CON00802129), Bunker Hill Mining Area and Metallurgical Complex (EPA ID IDD048340921), Upper Tenmile Creek Mining Area (EPA ID MTSFN7578012), United Nuclear Corp. (EPA ID NMD030443303), Cimarron Mining Corp. (EPA ID NMD980749378), Tar Creek (Ottawa County (EPA ID OKD980629844), Fremont National Forest/White King and Lucky (EPA ID OR7122307658), Brewer Gold Mine (EPA ID SCD987577913), Barite/Nevada Goldfields (EPA ID SCN000407714), Gilt Edge Mine (EPA ID SDD987673985), Nelson Tunnel/Commodore Waste Rock (EPA ID CON000802630), Blackbird Mine (EPA ID IDD980725832).

Note that, based on a review of mining practices, it is likely that most, if not all, 35 non-operating sites reviewed generated waste rock. Documentation specifically described waste rock disposal at 19 sites, however.

the acid-generating process. Additionally, the EPA identified the site's waste rock piles themselves as sources of contamination, affecting both local groundwater and soil.[529]

In addition, at five of the non-operating mining and processing CERCLA sites sampled, waste rock disposal that occurred after 1980 was responsible for releases.

- Gold was discovered at the **Summitville Mine** (EPA ID COD983778432) site in Rio Grande County, Colorado, in 1870; surface mining began in 1875. Surface and underground mining began in earnest in 1925 and continued on an intermittent basis through 1991. Operators removed waste rock along with ore from the underground mine and deposited it at the adit entrances; the practice continued from the start of mining operations through the 1980s. Numerous operations created sulfuric acid and sulfates, and subsequent AMD which loaded metal concentrates and acidic water into the local environment. One waste deposition area, the Cropsy Waste Pile, incorporated low grade ore, overburden, and waste rock, covered 35 acres of land, and rose as high as 56.41 meters. Nearby operation of a heap leach pad caused the waste pile to flood and created five million gallons of "highly contaminated water." The EPA also identified the North Pit Waste Dump, containing overburden and waste rock, as a source of AMD.[530]
- The **Brewer Gold Mine** (EPA ID SCD987577913) is a non-operating open-pit gold mine in Jefferson, South Carolina. Mineral extractive activity may have occurred at the area as early as the 1500s and gold was discovered at the site in 1828. Contemporary mining operations did not begin until 1987, though, and ended in 1995. Waste rock was either used for facility construction or hauled to a disposal area. The ore was processed using cyanide heap leach methods. When mining activity ceased, the operator backfilled the pits with leached ore and waste rock. Metals and acid still present in the former waste rock dump area seep to a sediment pond, without which the seep would enter a local creek. The waste rock itself, now in the pit, is a source of groundwater leaching.[531]
- Located in McCormick, South Carolina, the **Barite/Nevada Goldfields** (EPA ID SCN000407714) site encompasses the Barite Hill gold and silver surface mine, operated by Nevada Goldfields, Inc. from 1989 until 1994. The site was referred to EPA in 2006. The ore was processed at a heap leach facility. Operations produced 250,000 cubic yards of acid generating pyritic waste rock, leading to AMD. The runoff and erosion flows to an acid collecting pit lake with a pH of 2, now in danger of overflow or failure. If the

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[529] U.S. EPA Region 8, *Captain Jack Superfund Site Record of Decision* (Washington, DC: U.S. Government Printing Office, 2008).

[530] U.S. Environmental Protection Agency, *Superfund Record of Decision: Summitville Mine, EPA ID: COD983778432, OU 00*, Rio Grande County, CO (Washington, DC: U.S. Government Printing Office, 1994).

[531] "NPL Site Narrative: Brewer Gold Mine," U.S. Environmental Protection Agency. Accessed November 25, 2011, at: http://www.epa.gov/superfund/sites/npl/nar1725.htm; and U.S. Environmental Protection Agency Region 4, *Interim Record of Decision, Summary of Remedial Alternative Selection, Brewer Gold Mine, Jefferson, Chesterfield County, South Carolina* (Washington, DC: U.S. Government Printing Office, 2005).

structural integrity of the lake were compromised, it would result in a catastrophic release of acidic metals laden water into adjacent surface water. EPA added the site to the NPL in April, 2009.[532]

- The **Nelson Tunnel/Commodore Waste Rock** (EPA ID CON000802630) is an underground mine site located near Creede, Colorado. The site was primarily a silver mine, but operators also extracted gold, copper, lead and zinc. It was active from 1876 through 1989. EPA added the site to the NPL in 2008. An adit at the site empties directly into nearby surface water and is a source of acidic metal laden water. In 2005, a less-than-20-year flood event caused a catastrophic failure of the 200,000 cubic yard waste rock pile, which partially collapsed and released arsenic, cadmium, lead, and zinc into the local environment; specifically, the pile fell into nearby surface water.[533]
- The **Blackbird Mine** (EPA ID D980725832) cobalt mine is located near Salmon, Idaho. An underground and surface operation, it was active from 1883 through 1982. Over the course of its life, the mine generated 4.8 million tons of waste rock in numerous depositions. AMD from the piles, as well as the underground workings, tailings impoundment, and direct-discharged tailings have distributed arsenic, cobalt, and copper into local surface water.[534]

Currently Operating Facilities

Documents confirmed that 21 of the 70 currently operating facilities sampled for this review generate waste rock.[535] Of those 21 facilities, waste rock was responsible for releases at five of them. Operations at many of the facilities started before the passage of contemporary

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[532] "NPL Site Narrative: Barite Hill/Nevada Goldfields," U.S. Environmental Protection Agency. Accessed November 25, 2011, at: http://www.epa.gov/superfund/sites/npl/nar1784.htm; and U.S. Environmental Protection Agency, Region 4, "Action Memorandum to Franklin E. Hill, Director of the Superfund Division, re: Barite Hill Mine Site" (18 September 2007).

[533] "Superfund Site Description: Nelson Tunnel/Commodore Waste Rock," U.S. Environmental Protection Agency. Accessed January 6, 2012, at: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0802630; and U.S. Environmental Protection Agency, Region 8, *Remedial Investigation: Nelson Tunnel/Commodore Waste Rock Pile* (Washington, DC: U.S. Government Printing Office, 2011).

[534] U.S. Environmental Protection Agency Region 10, Office of Environmental Cleanup, *Blackbird Mine Superfund Site Record of Decision* (Washington, DC: U.S. Government Printing Office, 2003).

[535] ArcelorMittal Minorca (MSHA ID 2102449), Asarco Silver Bell (MSHA ID 0200134), CML Iron Mountain (MSHA IDs 4201927 and 4202624), Coeur Kensington (MSHA ID 5001544), Coeur Rochester (MSHA ID 2601941), Florida Canyon Mine (MSHA ID 2601947), Freeport McMoRan Henderson (MSHA ID 0500790), Freeport McMoRan Morenci (MSHA ID 2000024), Freeport McMoRan Tyone (MSHA ID 2900159), Hecla Greens Creek (MSHA ID 5001267), Geo Nevada Spring Valley (MSHA ID 2602470), Halliburton Rossi (MSHA ID 2602239), Kinross Crown Resources Buckhorn Mine (MSHA ID 4503615), Rio Tinto Kennecott Bingham Canyon (MSHA IDs 4200149 and 4201996), Robinson Nevada (MSHA ID 2601916), Sixteen to One Mine (MSHA ID 401299), Mosaic South Pasture Hardee (MSHA ID 0800903), US Silver Galena (MSHA ID 1000082), Veris Gold – Jerritt Canyon (MSHA IDs 2602742 and 2601621), Monsanto/P4 South Rasmussen-Blackfoot Bridge (MSHA ID 1001854).

Note that it is likely, based on a review of mining practices respective to waste rock, that most if not all of the current sites that have active mines reviewed above generated waste rock. We were only able to find documentation of waste rock at the above 21 sites, however. Note, too, that Cyprus Tohono was part of both the non-operating site sample and the currently operating facility sample.

environmental legislation and the adoption of currently used waste rock disposal practices. At all five of the facilities that experienced waste rock-related releases, however, the releases occurred were the result of practices currently in use.

- **ArcelorMittal Minorca** (MSHA ID 2102449) is an iron mining and processing facility located in Virginia, Minnesota. Mining at the site began in 1974 and an iron pellet processor was constructed at the site in 1977. Mittal Steel USA began operating the site in 2007. Mittal codisposes and slurries waste rock low in iron with tailings, and pumps the mixture to a storage basin three miles from the mine. Three failures in the tailings and waste rock pipe occurred in 2013 and 2014, discharging 8,500 cubic yards of tailings and waste rock and affecting 15.3 acres of wetlands, potentially destroying the area's ability to function as a natural aquatic habitat and filtration system. It is unclear when the tailings and waste rock pipe and impoundment were installed.[536]
- The **Rio Tinto Kennecott Bingham Canyon** site (MSHA IDs 40122149 and 42011996) is an open-pit copper, gold, silver, and molybdenum mine located near Salt Lake City, Utah. Open-pit activity at the site started in 1906. Kennecott Copper Company, now a subsidiary of Rio Tinto, has operated the site since 1936. As part of its operations, Kennecott deposited waste rock on the slopes of the nearby Oquirrh Mountains. The waste rock dumps leached metals-rich acidic water first through an unlined reservoir and then into a groundwater plume that extended 72 square miles. The State of Utah took legal action against Kennecott as a result of the contamination in 1986; as a result of a consent decree reached in 2007, Kennecott (by then a subsidiary of Rio Tinto) agreed to treat the contaminated groundwater for the next forty years.[537]
- The **Veris Gold Jerritt Canyon Site** (MSHA IDs 2602742 and 2601621) is a gold mine located in Elko County, Nevada, first operated in 1980 and now operated by Queenstake Resources USA, Inc., a wholly owned subsidiary of Yukon-Nevada Gold Corporation. The site includes twelve closed surface mines (four reclaimed) and five underground mines. The mine has four rock disposal areas, constructed in the early 1980s, designed to minimize erosion by draining precipitation runoff toward the interior of the disposal. This design resulted in seepages from the toe of the disposals, however, with excessive amounts of total dissolved solids (primarily sulfates and magnesium). The seepages were

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[536] "Pipeline, Storage Basin Failures Send Ore Tailings and Road Aggregate into Wetlands," Minnesota Pollution Control Agency, last updated 24 June 2015, accessed 10 December 2015 at: http://www.pca.state.mn.us/index.php/about-mpca/mpca-news/current-news-releases/pipeline-storage-basin-failures-send-ore-tailings-and-road-aggregate-into-wetlands-2-enforcement-actions-result.html; and "ArcelorMittal Pays Fines, Cleans Up," *Hibbings Daily Tribune* (26 June 2015).

[537] "Earthworks Factsheet: Problems with Bingham Canyon Mine," Earthworks, published 2011. Accessed December 29, 2015, at https://www.earthworksaction.org/files/publications/FS_Problems_BinghamCanyon_2011_low.pdf; and U.S. Environmental Protection Agency Region 8 and Utah Department of Environmental Quality, *Five-Year Review Report: Kennecott North Zone Superfund Site, Salt Lake County and Tooeele County, Utah* (Washington, DC: U.S. Government Printing Office, 2014).

detected in the late 1990s.[538]

- Operations at the **Monsanto/P4 South Rasmussen-Blackfoot Bridge** (MSHA ID 1001854) site, located near Soda Springs, ID, started in 1998. The site is currently operated by P4 Production LLC, a subsidiary of Monsanto. Operations include a surface mine and phosphate processing facility. In 2011, P4 Production reached a consent decree as a result of CWA violations resulting from seepages at the mine site. P4 Production deposited overburden and waste rock from the mine site at the Horseshoe Overburden Area, which discharged effluent containing selenium, cadmium, nickel, and zinc into local surface water because of rain and weathering.[539]
- The **ASARCO Silver Bell** (MSHA ID 0200134) site is a complex of four surface copper mines with a combination heap leach and solvent extraction/electrowinning processing operation located in Pima County, Arizona. Commercial mining and smelting at the site began in 1880. The site was not in operation between 1984 and 1997, at which point the solvent extraction/electrowinning circuit was installed. During a 1993 inspection in advance of the facility reopening in 1997, the ADEQ discovered that three surface streams passed near or underneath waste rock dumps contaminated with leach solution.[540]

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[538] Queenstake Resources USA, Inc., *2009 Annual Work Plan: Jerritt Canyon Mine* (April 2009); and Nevada Division of Environmental Protection, "Fact Sheet: Water Pollution Control Permit NEV 0000020 (Renewal 2015, Rev. 00)" (2015).

[539] "For Immediate Release: Idaho Mining Company Agrees to Pay $1.4 Million Penalty to Settle Alleged Clean Water Act Violations," U.S. Department of Justice, Environmental and Natural Resource Division, Office of Public Affairs, released 20 April 2011. Accessed December 29, 2015, at: http://www.justice.gov/opa/pr/idaho-mining-company-agrees-pay-14-million-penalty-settle-alleged-clean-water-act-violations.

[540] U.S. Environmental Protection Agency, Office of Solid Waste, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

C. Tailings Management

Introduction

Tailings are the waste material created when valuable minerals or metals have been physically or chemically separated from ore. All beneficiation procedures generate tailings, in addition to mineral processing activities. Tailings usually take the form of a slurry (e.g., wet tailings), but may also undergo dewatering and disposal as paste or filtered tailings. Depending on the commodity and the beneficiation process, tailings may contain a variety of hazardous materials, both originating from geologic components of the ore or chemicals introduced during processing, and therefore require proper disposal and storage. Environmental concerns arise from the possibility of releases during the transportation of tailings from processing facility to a storage or disposal facility, and from the storage or disposal facility itself, both during operations and after facility closure.[541]

Past operations often disposed of tailings directly into local environments without any effort to contain them. Current operations are subject to a regulatory framework that addresses waste disposal before the start of mining and processing activity, sets performance standards, and requires an approved reclamation plan. As a result, management practices have improved, but releases continue. Many currently operating facilities and recently closed sites have operated for over a century, so it is unclear if releases occur from newly constructed impoundments designed using best management practices to prevent releases or from previous impoundments constructed before practices changed. Additionally, even after site closure, tailings remain a potential source of contamination. They are often a focus of reclamation and closure plans and require the application of a post-closure cover and continued maintenance and monitoring.

Past and Current Use

Until the middle of the 20th century, cost-effectiveness and convenience were the overriding determinants in tailing deposition practices, with tailings discharged into local waterways or drainages.[542] Early tailing impoundments, dating from the 19th and early 20th century, allowed operators to recycle water and chemicals used in processing and limited effects of tailings

[541] In this discussion, "tailings storage facility" means any location where tailings are stored (including uncontained piles). The use of the term "impoundment" means structural containment. A tailings "pond" is specifically a deposition site for slurry tailings (tailings transported to the storage site in liquid form).

[542] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994).

disposal on local agriculture.[543] Operators deposited tailings in slurry form in unlined embankments or ponds constructed of local material.[544]

Although the practice of constructing tailings pond impoundments from local soil was commonplace by the 1970s, a combination of widely-publicized impoundment failures,[545] public concern over hazardous cyanide and uranium tailings,[546] and increased environmental regulation encouraged the development of more secure and stable tailings impoundment systems. Impoundment design changed in part because technology and engineering advanced, allowing for increased data collection and detection and computer modeling of embankments.[547] The specific evolution of tailings management since 1980 has proceeded down two tracks: lining tailings ponds with synthetic materials and decreasing the permeability of the tailings themselves.[548]

The use of synthetic films as liners in the mining industry began in the 1940s. The practice grew in popularity with the use of PVC at heap leach facilities in the 1970s, and the use of high density polyethylene (HDPE) for heap leach pads and tailings impoundments in the 1980s.[549] Synthetic liners have been increasingly common since then. An operator can also decrease the permeability of a tailings impoundment through the use of clay-amended soil liners or bentonite-amended clay liners, sometimes in conjunction with a synthetic liner.[550]

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[543] See Jon Engels, "History of Tailings Storage Methods," Tailings.info, website developed as part of PhD Dissertation "An Expert Management System for Surface Tailings Storage," submitted to the University of Leeds (2006). Accessed November 20, 2015, at: http://www.tailings.info/basics/history.htm.

[544] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p.423.

[545] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 412.

[546] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 436.

[547] Jack Caldwell and Dirk Van Zyl, "Thirty Years of Tailings History from Tailings & Mine Waste," Paper Presented at Tailings and Mine Waste 2011 (Vancouver: 6-9 November 2011).

[548] Jack Caldwell and Dirk Van Zyl, "Thirty Years of Tailings History from Tailings & Mine Waste," Paper Presented at Tailings and Mine Waste 2011 (Vancouver: 6-9 November 2011); and D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 426.

[549] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 426.

[550] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 424-425; and Chris Athanassopoulos, Alyssa Kohlman, Michael Henderson, and Joseph Kaul, "Evaluation of Geomembrane Puncture Potential and Hydraulic Performance in Mining Applications," paper presented at Tailings and Mine Waste 2008 (Vail, CO: 19-22 October 2008).

Since 1973, operators have explored the possibility of thickening tailings to various levels of solidity: thick but still a slurry, paste (no flow velocity), or dry stacked.[551] Although the processes listed increase costs, they reduce the permeability of the tailings and are now a "standard method of tailings disposal." [552]

Technical Description

Tailings are the fraction of ore that remains after valuable minerals or metals have been removed. Typically, because crushing and grinding of the ore are precursors to most physical and chemical extraction processes, tailings are clay, silt, or sand-sized particles. When the desired mineral or metal has been removed through extraction and beneficiation, wet tailings are discharged in a dilute slurry at a 20-45 percent solids ratio, or can be physically treated to slurry at a solids ratio of 55 to 60 percent and conveyed through a pipeline to an impoundment facility.[553] Because of the liquid state of the tailings, ponds are the most commonly used repository. Ponds can be constructed or formed from the topography adjacent to the mill site from tailings or waste rock materials, and are bounded by low-permeability embankments or dams. On the other hand, water may be removed from the tailings altogether, creating solid paste (e.g., dry)[554] tailings which are then stacked in a tailings storage facility.[555] Operators may also dispose of tailings by leaving waste-in-place in tailings storage facilities, backfilling abandoned mines, or, in some cases, disposal may occur through various forms of subaqueous disposal. [556, 557]

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[551] Jon Engels, "Deposition Methods of Tailings," Tailings.info, website developed as part of PhD Dissertation "An Expert Management System for Surface Tailings Storage," submitted to the University of Leeds (2006). Accessed November 19, 2015, at http://www.tailings.info/disposal/deposition.htm.

[552] Jack Caldwell and Dirk Van Zyl, "Thirty Years of Tailings History from Tailings & Mine Waste," Paper Presented at Tailings and Mine Waste 2011 (Vancouver: 6-9 November 2011).

[553] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 428 and 431.

[554] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 431-432.

[555] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 443.

[556] Jon Engels, "Storage Techniques – In-Pit" and "Storage Techniques – Backfill of Tailings to Underground Workings," Tailings.info, website developed as part of PhD Dissertation "An Expert Management System for Surface Tailings Storage," submitted to the University of Leeds (2006), accessed November 20, 2015, at: http://www.tailings.info/storage/inpit.htm and http://www.tailings.info/storage/backfill.htm.

[557] Jon Engels, "Storage Techniques – Offshore Disposal," Tailings.info, website developed as part of PhD Dissertation "An Expert Management System for Surface Tailings Storage," submitted to the University of Leeds (2006), accessed November 20, 2015, at: http://www.tailings.info/storage/offshore.htm. Note that offshore marine discharge is illegal in the United States, but tailings can be disposed of in an existing pond in conjunction with the construction of some form of impoundment, or a pond may be constructed on top of impounded tailings. See also D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 438.

The tailings slurry contains water, waste particles, and uneconomic portions of the commodity and other trace elements of potential environmental concern. At a later date, with more sophisticated and cost-efficient extraction processes or increased commodity prices, tailings may be subject to reprocessing as previously uneconomic grades of ore become economically viable.[558] Additionally, depending on the commodity and the processing method, tailings may contain chemical residues inherent to processing. For example, milling operations that practice flotation or leaching may produce tailings containing reagents such as lime or glycol ether and lixiviants including acids and cyanide.[559]

Of the hundreds of active hardrock mining and mineral processing facilities[560] in the United States, many have at least one and often several tailings storage facilities.[561] In most mining sectors, the ore mined consists largely of waste material, which create tailings. In cases where the commodity is rare but valuable, such as gold, processing generates tons of tailings for every fraction of an ounce of commodity produced. For commodities such as copper, advanced extraction technologies and economies of scale have made the mining of low-grade ore (which contains large proportions of waste material) cost-effective.[562] Thus, the volume of tailings that mine and mill operators need to dispose of has increased over time. Further, tailings have a long containment horizon because they stay in place after a mine ceases its activity – experts evaluate their monitoring needs in terms of at least 200 years – and therefore planning is required for their long-term stability and maintenance.[563]

The subsections below discuss two considerations for operators disposing of and managing tailings: the appropriate storage facility for the tailings and storage facility liner systems.

- **Tailings Storage Facilities** are the ultimate repositories for both slurry and paste tailings, unless the operator uses the tailings as mine backfill. Dewatered paste and filtered tailings are often deposited in a lined or unlined surface impoundment with a drain and an

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[558] Monica O. Mendez and Raina M. Meier, "Phytostabilization of Mine Tailings in Arid and Semiarid Environments – An Emerging Remediation Technology," *Environmental Health Perspectives* 116:3 (March 2008), p. 279.

[559] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 429.

[560] For "hundreds of active hardrock" facilities, see United States Department of Labor, Mine Safety and Health administration, Mine Data Retrieval System; accessed December 7, 2015, at: http://www.msha.gov/drs/drshome.htm. For the purposes of this paper, phosphate mining and primary processing and uranium mining and primary processing are included under the definition of "hardrock mining."

[561] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 1.

[562] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 1; and National Academy of Sciences, National Research Council, Committee on Technologies for the Mining Industry, Committee on Earth Resources. 2002. Evolutionary and Revolutionary Technologies for Mining.

[563] Jack Caldwell and Dirk Van Zyl, "Thirty Years of Tailings History from Tailings & Mine Waste," Paper Presented at Tailings and Mine Waste 2011 (Vancouver: 6-9 November 2011).

embankment.[564] To complete reclamation, dry tailings are capped with topsoil which may be planted to facilitate stabilization.[565]

Slurry impoundments feature embankments constructed from local soil, waste rock, or tailings themselves, in conjunction with the natural topography surrounding the facility.[566]

- **Liner systems**, now widely used in tailings impoundments (particularly for uranium or cyanide tailings), are multilayer structures designed to reduce the permeability of a containment structure to prevent seepage.[567] A typical liner may combine low permeability natural material such as clay, geosynthetic or synthetic geomembranes, and drainage layers and sumps with seepage detection systems, as well as covers to protect the layers from the elements.[568]

  Liners come in a variety of materials. Geosynthetic liners involve the amendment of soil or clay with low permeability material. Geomembranes are usually constructed from PVC or polyethylenes.[569] Even with advancements in synthetic or amended liners, when calculating permeability of liner systems it is assumed there is one hole per acre of liner.[570]

Potential Sources of Hazardous Substances

Tailings contain waste material (including uneconomical amounts of the commodity) and residue of the extractive chemicals. The specific hazardous substances they contain depend on the commodity, the geochemistry of the commodity-bearing ore, and the process. Additionally,

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[564] Jack Caldwell and Dirk Van Zyl, "Thirty Years of Tailings History from Tailings & Mine Waste," Paper Presented at Tailings and Mine Waste 2011 (Vancouver: 6-9 November 2011).

[565] Monica O. Mendez and Raina M. Meier, "Phytostabilization of Mine Tailings in Arid and Semiarid Environments – An Emerging Remediation Technology," *Environmental Health Perspectives* 116:3 (March 2008), p. 279.

[566] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 7-10; and D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 434-435.

[567] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 426 and 436.

[568] Chris Athanassopoulos, Alyssa Kohlman, Michael Henderson, and Joseph Kaul, "Evaluation of Geomembrane Puncture Potential and Hydraulic Performance in Mining Applications," paper presented at Tailings and Mine Waste 2008 (Vail, CO: 19-22 October 2008).

[569] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 426-427.

[570] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 428.

tailings can contain trace elements that are mobilized by processing and through AMD or alkaline leaching. These naturally co-occurring substances (e.g., arsenic and mercury from gold ore) are liberated from rock and can present health and environmental concerns.

The releases described below pertain to tailings and tailings storage facilities while a mine or processing facility is operational, although tailings management remains relevant long after the mine and processing facility have closed. It is recommended that tailings containment strategies be evaluated at horizons of at least 200 years.[571] Reclamation plans and continued maintenance and monitoring are necessary to prevent or mitigate post-closure releases.

State and Federal Regulations

Current operations are subject to substantially more comprehensive regulatory requirements relative to past operations, where discharges and abandonment were common.[572] At both the federal and state level, land management and environmental regulations address potential environmental risks from tailings disposal and management.

Mining and processing operations may be subject to preliminary environmental planning and assessment, operational requirements and performance standards, and reclamation requirements.

Federal Regulations

Federal agencies have promulgated rules regarding tailings management. These include:

- **Solid waste.** RCRA Section 3001(b)(1) (the Bevill Amendment) exempts solid waste from extraction and beneficiation and 20 processing wastes from regulation as hazardous waste under RCRA Subtitle C. State and local governments implement solid waste management guidelines under RCRA Subtitle D. EPA's authority under Subtitle D is limited; its primary role is to promulgate sanitary landfill criteria to prevent adverse effects on health or the environment. As of 2013, EPA has not finalized any solid waste management requirements specifically applicable to the disposal of Bevill waste.[573]

[571] Jack Caldwell and Dirk Van Zyl, "Thirty Years of Tailings History from Tailings & Mine Waste," Paper Presented at Tailings and Mine Waste 2011 (Vancouver: 6-9 November 2011).

[572] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994).

[573] L. Luther, "Background on and Implementation of the Bevill Bentsen Exclusions in the Resource Conservation and Recovery Act: EPA Authorities to Regulate 'Special Wastes,'" *Congressional Research Service* R43149 (Washington, DC: U.S. Government Printing Office, 2013).

Exhibit 2.C.1. Potential Releases Associated with Tailings Disposal

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Embankment Failure	Embankment failure occurs when the structures bounding an impoundment are compromised due to structural instability, rotational sliding, seismic events and liquefaction (weakening of soil through shaking), or erosion from tailings that corrode impoundment walls. Embankment failure results in the release of tailings into local environment and, if located near a watershed, dispersal of tailings downstream.[574]	• Thorough geotechnical site characterization prior to construction.[575] • Monitor embankment stability.[576] • Add to embankment when necessary to contain tailings. • Include impervious core in embankment design.[577] • Use downstream embankment design.[578] • Construct embankment out of materials that resist liquefaction.[579] • Install liner in impoundment above tailings line to prevent corrosion.
Mine Drainage and Seepage	MIW (e.g., acid, alkaline, or neutral mine drainage), runoff originating from exposed tailings, is also a distinct risk. Water percolating through uncovered or otherwise exposed disposal facilities may contain residual process chemicals or mobilized	• Installing an appropriate liner system that can incorporate leak detection and drainage systems.[583] • As part of mine design targeted extraction

[574] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p.36-38; and D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 440-441.

[575] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 18-21.

[576] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 38; and D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 442.

[577] D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 435.

[578] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 24, 26-28; and D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 435.

[579] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 38; and D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p.440-441.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
	contaminants. While residual chemicals are usually recycled with tailings water, trace elements from the ore are housed in the tailings and represent longer-term sources of possible contamination.[580] Further, drainage may react with sulfide minerals, creating acid drainage (which further mobilizes contaminants). [581] A variety of factors affect the rate of acid drainage generation from tailings including the water level within the pile, exposure to oxygen, and the presence of bacteria. Seepage involves the tailings breaching the storage facility and traveling into the groundwater or surface water. Although most commonly experienced with slurry tailings, seepage can also occur with thickened tailings, especially when exposed to precipitation. Breach can happen as a result of storage facility failure or through runoff that passes through the facility and carries tailings material with it. Seepage can occur in lined impoundments when the liner fails.[582] Further, impoundment failure via mine drainage or seepage and	techniques such as selective mining and avoidance could be used to minimize mining of ore resulting in leach tailings that could result in MIW.[584] • Production of paste or dry dewatered leach tailings to reduce potential for MIW.[585] • During operations special handling techniques such the addition of alkaline materials or amendments can be used to reduce potential for AMD from leach tailings.[586] • At closure leach tailings areas can be reclaimed using dry and wet covers to lessen or minimize discharges of MIW.[587]

583 U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 45-48.

580 See D.J.A. Van Zyl and J.N. Johnson, eds., "Chapter 8: Systems Design for Site Specific Environmental Protection," in *Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining*, ed. J.J. Marcus (London: Imperial College Press, 1997), p. 438 for recycling of supernatant with tailings water through decanting.

581 U.S. Environmental Protection Agency, Office of Solid Waste, Special Waste Branch, *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals* EPA 530-r-94-013, Volume 2: Gold (Washington, DC: U.S. Government Printing Office, 1994).

582 U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 43-44.

584 The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.1.

585 The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.8.

586 The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.4.2.

587 The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Pipe Failure	Slurry tailings are piped from the processing facility to the impoundments. If the pipe fails at any point in the transportation process it discharges tailings to the local environment.[588]	• Monitor pipe stability regularly. • Install leak detection systems.[589]
Untreated Discharge	At processing facilities that do not reclaim water from tailings ponds, wastewater is sometimes treated and released into local waterways. If treatment fails, tailings water with constituent hazardous substances can be released.	• Install monitor for effluent discharge system.[590] • Capture using various hydrogeologic controls (e.g., cutoff wells, grout curtains, seepage controls).[591] In the event the mine drainage requires treatment prior to discharge, either during operations or post-closure, a variety of active, passive and in situ mine drainage treatment techniques are potentially applicable.[592]

[588] U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 30.

[589] See best practices for seepage control. Pipe failure leads to seepage from the fail point. U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 45 and 48.

[590] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2.

[591] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.5.1.

[592] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 7.5.

TYPE OF RELEASE	DESCRIPTION	MANAGEMENT PRACTICES
Fugitive Dust	Fugitive dust can occur with both slurry tailings, when the tailings form a beach in the impoundment pond, or with thickened tailings. In high wind conditions fugitive dust can travel off-site, contaminating the local environment.[593]	• Manage tailings distribution to maximize surface moisture. • Spray tailings with water regularly. • Apply a dust suppressant on the tailings impoundment. • Crimp in straw to minimize erosion. • Monitor tailings impoundment daily.[594] • At closure, dry, wet, or vegetative covers can be used to lessen or minimize fugitive dust emissions.[595]

[593] See U.S. Environmental Protection Agency, *Technical Report: Design and Evaluation of Tailings Dams* EPA530-R-94-038 (Washington, DC: U.S. Government Printing Office, 1994), p. 2; for an example, see fugitive dust releases at the Climax Molybdenum Mine (MSHA ID 0502256), from U.S. Environmental Protection Agency, *Draft: Mining Waste Release and Environmental Effects Summary for the State of Colorado* (Washington, DC: U.S. Government Printing Office, 1994).

[594] All of the above from "Morenci Facts from FCX: Tailings Dust Management at Morenci," Freeport-McMoRan Copper & Gold Company, updated May 2011. Accessed December 3, 2015, at: http://www.fcx.com/sd/pdf/morenci_tailings_dust_mgmt.pdf.

[595] The International Network for Acid Prevention, *Global Acid Rock Drainage Guide* (Santiago, Chile: International Network for Acid Prevention Operating Committee, 2009), 6.6.3.2; and Monica O. Mendez and Raina M. Meier, "Phytostabilization of Mine Tailings in Arid and Semiarid Environments – An Emerging Remediation Technology," *Environmental Health Perspectives* 116:3 (March 2008), p. 279.

Facilities sometimes dispose of Bevill-exempt wastes in the same waste management units as non-exempt hazardous wastes, though.[596] In situations where facilities combine tailings with other wastes that exhibit hazardous characteristics, the waste mixtures may fall under RCRA Subtitle C regulations.

- **Water.** Untreated tailings may not be discharged into surface waters.[597] To comply with water quality standards under the CWA, mine operators must obtain permits under NPDES for any discharge of pollutant from a point source to waters of the United States.[598] For many hardrock commodities, EPA has promulgated ELGs requiring technology-based controls and establishing specific water quality standards.[599] These requirements address both mine drainage and process wastewater, which includes water contained in tailings. For discharges or pollutants not covered by the ELGs, EPA or the delegated state authority incorporates limits into permits on a site-specific basis. The NPDES program applies to both active and inactive mines, as well as abandoned mines where legally responsible owners or operators of point sources can be identified.

Runoff from tailings impoundments, spent ore piles, and waste rock piles may be regulated under NPDES stormwater permits.[600] Stormwater permits regulate stormwater contaminated by contact with material from mining activities, primarily requiring site-specific pollution prevention planning and/or implementation of mitigation practices.[601] These include treatment requirements, operating procedures, practices to control runoff, and monitoring.

While EPA issues and oversees point-source discharge permitting under Section 402 of the CWA, the USACE issues "dredge and fill" permits under Section 404 of the CWA. Under CWA Section 404, mining operations may need to obtain a permit from USACE to address the discharge of dredged or fill materials into surface water, including wetlands. In areas with

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[596] An EPA survey of 106 facilities in 1989 indicated that 20 facilities placed mixtures of Bevill-exempt and non-exempt wastes in the same waste management unit. See: U.S. Environmental Protection Agency, *Mineral Processing Facilities Placing Mixtures of Exempt and Non-Exempt Wastes in On-site Waste Management Units: Technical Background Document Supporting the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 2013).

[597] U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003).

[598] Point sources are defined broadly, includes any discernable, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, or container. "Waters of the United States" includes navigable waters, tributaries, interstate waters, intrastate waters used by interstate travelers, or for industrial purposes by industries engaged in interstate commerce. Generally, mining operations would fall under the Clean Water Act for process wastewater, mine drainage, and stormwater. See: U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003).

[599] For example: 40 CFR 436 (mineral mining and processing); 40 CFR 440 (ore mining and dressing); 40 CFR Part 421 (nonferrous metals manufacturing).

[600] Seepage to groundwater is not considered a point source, and is not regulated under the Clean Water Act. The classification of point and nonpoint discharges from mining operations has evolved over time. For more information regarding current definitions of point sources from mining operations, see: *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010)

[601] Best management practices for stormwater permits are described at 40 CFR 122.2.

streams, wetlands, or lakes, construction and ongoing modifications of tailings storage facilities may trigger this requirement. Some regulatory uncertainty exists regarding how mining overburden, slurry, and tailings are regulated under the CWA, because of different definitions of fill material used by EPA and USACE. Thus, Section 404 permits have been issued for mining operations outside of NPDES permitting requirements.[602]

Mining operations on public federal land are subject to additional regulation. According to the BLM Section 3809 rules, mining operations must prevent unnecessary or undue degradation, which includes managing all tailings, rock dumps, deleterious material or substances and any other waste produced from mining operations.[603] BLM guidance indicates that proper disposal of mining wastes must involve siting of tailings facilities to minimize potential for environmental impact. Further, operators must conduct reclamation to maximize long-term stability and minimize the formation and release of leachate.[604] Requirements include:

- Operators must have low-permeability liners or containment systems to minimize the release of solution to the environment using best available technology, and must monitor for potential contaminant releases from tailings ponds.
- Operators must design, construct, and operate impoundments to contain precipitation from a local 100-year, 24-hour storm event.
- **Air contaminants.** EPA has limited ability to control fugitive dust emissions under the CAA.[605] In some cases, specific types of ores are subject to additional regulations addressing hazardous air pollution. For example, UMTRCA mandates special closure designs for uranium mill tailings ponds to prevent radon gas releases.[606]
- **Safety (impoundment failure).** The MSHA also requires inspections and safety standards for impoundments, retention dams, and tailings ponds, with a focus on mine worker safety.[607] MSHA publishes engineering and design guidelines for coal refuse

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[602] C. Copeland, "Controversies over Redefining 'Fill Material' Under the Clean Water Act," *Congressional Research Service* RL31411 (Washington, DC: U.S. Government Printing Office, 2013).

[603] 43 CFR Part 3809

[604] U.S. Department of the Interior, Bureau of Land Management, *Surface Management Handbook* H-3809-1 (Washington, DC: U.S. Government Printing Office, 2012), Section 5.3.2

[605] U.S. Environmental Protection Agency Region 10, *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (Washington, DC: U.S. Government Publishing Office, 2003).

[606] UMTRCA, PL 95-604.

[607] 30 CFR Part 57, Subpart S. For more information, see: "Dam Safety Standards and Technical Guidance," MSHA. U.S. Department of Labor. Accessed October 30, 2015 at: http://www.msha.gov/DamSafety/DamSafetyTechGuidance.asp., and N. Merrifield. MSHA. U.S. Department of Labor. Reissue of I09-IV-1 Procedures for Documenting Inspections of Dams on Initial and Subsequent Regular Inspections. Procedure Instruction Letter No. I13-IV-01. May 31, 2013. Accessed December 2, 2015, at: http://www.msha.gov/regs/complian/PILS/2013/PIL13-IV-01.asp.

facilities, but not metal and nonmetal mines. The FEMA is also charged with administering a national dam safety program that includes tailings structures.[608]

State Regulations

Many states have operational, technology, and performance-based standards for general mining waste management and disposal in state solid waste regulations, state groundwater pollution laws, dam safety programs, or state mining laws. Generally, state and local governments implement solid waste management guidelines under RCRA Subtitle D, establishing operating and closure requirements that apply to all types of industrial waste disposal units. States with delegated authority also implement CWA regulations, with state programs being at least as stringent as federal regulations. Several state regulations specifically manage mine tailings, although in some cases tailings with no chemical additives are excluded from regulation. For example:

- **Alaska's** Department of Environmental Conservation Solid Waste Disposal Permit makes tailings from hardrock mines and tailings from placer mines that have been amalgamated or chemically treated subject to the State solid waste management general standards and requirements, which usually necessitate pre-operational, operation, and post-closure monitoring.[609]Tailings that have not been chemically treated, however, are not subject to regulation.
- **Arizona's** Groundwater Permit requires mines in active groundwater management areas to reduce water loss from tailings impoundments.[610]
- **California** manages mining wastes through the state's Porter-Cologne Water Quality Control Act. All mining units, including tailings structures, must comply with siting and construction standards. Disposal and management regulations for mining waste establish monitoring, closure, and maintenance requirements, which are based on wastes' potential hazard to water.[611]
- **Idaho's** Dam Safety Program regulates tailings structures through dam and impoundment structure requirements. The state oversees the construction, enlargement, alteration, repair, operation, and maintenance of dams and impoundments.[612]

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[608] Federal Emergency Management Agency, *Strategic Plan for the National Dam Safety Program: Fiscal Years 2012 through 2016* FEMA P-916 (Washington, DC: U.S. Government Printing Office, 2012). Accessed December 1, 2015, at: https://www.fema.gov/media-library-data/8025e6039b9aebfa22e9f378347149c4/NDSP%20Strategic%20Plan_FEMA%20P-916.pdf.

[609] Title 18 AAC Chapter 60 - Solid Waste Management.

[610] ARS §45

[611] 27 CCR Div. 7.1

[612] Idaho Code 42-17; IDAPA 37.06.06; IDAPA 37.03.05

- **Montana's** Hard Rock Mining Reclamation Act specifies that milling operations are subject to permitting, requiring a detailed description of the design, construction, and operation of the mill, tailings, and waste rock disposal facilities, and best management practices are expected in the disposal of tailings and other waste.[613]
- **Nevada's** regulations on hazardous materials require that tailings from active and inactive uranium and thorium mills be disposed of in a safe and environmentally sound manner.[614]

Non-Operating Sites and Currently Operating Facilities

Many of the sites reviewed below began operations before the promulgation of major environmental laws since 1980. Mines and mineral processing sites have continued to experience releases, however, because of their tailings disposal practices. Operators process ever-lower grades of ore because of economies of scale, technological improvements, and rising metal prices. Processing low-grade ore means producing relatively more tailings, and exploiting economies of scale leads to increased production and processing overall. Thus, contemporary mining practices produce a higher percentage of tailings and in greater volume than ever before.

In the below sample, documents confirmed at least eleven non-operating sites or currently operating facilities that experienced tailings-related releases after 1980, out of a total of 105 sites reviewed.[615]

This review of contemporary mines did not capture information characterizing the scope and efficacy of reclamation and closure practices. Improper and failed reclamation have been the basis for past CERCLA actions at hardrock mines, and remains a consideration in the environmental performance of contemporary mines.

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[613] ARM 17.24.101-ARM.17.24.189

[614] NRS 459.300-NRS459.370

[615] The sample considered above includes phosphate mine and processing facilities. Those facilities recover a commodity from ore and the waste (gypsum or phosphogypsum) is slurried and sent to lined or unlined stacks. Phosphate rock mining wastes are included among the categories of exempt special wastes from RCRA Subtitle C regulations, the 1980 Solid Waste Disposal Act Amendments, and the EPA Report to Congress on Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale. See U.S. Environmental Protection Agency Region 10, Record of Decision: Declaration, Decision Summary, and Responsiveness Summary for Eastern Michaud Flats Superfund Site (June 1998). See 42 U.S.C. 6901–6992k, Sec. 3001(b)3)A)(i-iii); and U.S. Environmental Protection Agency, Report to Congress: Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining, and Oil Shale, delivered 31 December 1985 (EPA530-SW-85-033).

Non-Operating Sites

Documents confirmed that 17 of the 29 non-operating mining and processing CERCLA sites reviewed generated tailings.[616] Of those 17 sites, tailings were responsible for releases at 12 of the sites. Activity at many of the sites extended back before the widespread use of impoundments, liners, and other tailings containment strategies. Thus, releases were largely due to the direct discharge of tailings into the local environment or inadequate impoundment. For example:

- The **Gilt Edge Mine** (EPA ID SDD987673985) is located near Lead, South Dakota. The site was a gold, silver, copper, lead and zinc mine. The site had been operated intermittently since 1876; mining ceased in 1998. Operations included a cyanidation circuit and a countercurrent decanter. Previous operators either dumped their tailings bearing acid and metals directly into nearby Strawberry Creek or left them uncontained close to the water. In 1986, BMC received a permit to work the site and removed over 200,000 tons of relic tailings to use as part of its heap leach operation. As of the 1980s, tens of thousands of tons of acid-generating tailings were reported in the Creek; Strawberry Creek is still devoid of aquatic life.[617]

At three of the 17 sites, however, releases of tailings occurred during or after the adoption of currently used tailings management procedures. These two sites exhibited discharges due to poorly maintained tailings structures or improper disposal methods:

- The **Cimarron Mining Corporation** (EPA ID NMD980749378) site is located near Carrizozo, Lincoln County, New Mexico. The facility housed an agitation mill. Zia Steel Inc. first operated the facility as an iron processing site in the late 1960s, and remained active on the site until 1979. In 1979, Southwest Minerals Corporation (a/k/a Cimarron Mining Corporation) acquired the site and converted it to a precious metal processing circuit involving the use of cyanide salt and a metal stripper. The site operated two mills. One of the mills discharged tailings into three piles: "C," "I" and "K." The other mill had two lined impoundments, both of which had torn lining. The tailings storage facilities at both sites appear to have been constructed after 1979, because the previous tailings from Zia Steel Inc. were transported away from the site and used as fill. The New Mexico

[616] United Nuclear Corp. (EPA ID NMD030443303), Gilt Edge Mine (EPA ID SDD987673985), Bunker Hill Mining and Metallurgical Complex (EPA ID IDD048340921), Cyprus Tohono Mine (EPA ID AZD094524097), Tar Creek (Ottawa County) (EPA ID OKD980629844), Upper Tenmile Creek Mining Area (EPA ID MTSFN7578012), Asarco Inc. (Globe Plant) (EPA ID COD007063530), East Helena Site (EPA ID MTD006230346), Bueno Mill & Mine Site (EPA ID CON000802129), Summitville Mine (EPA ID COD983778432), Homestake Mining Co. (EPA ID NMD007860935), Cimarron Mining Corp. (EPA ID NMD0980749378), Fremont National Forest (EPA ID OR7122307658), Captain Jack Mill (EPA ID COD981551427), Silver Mountain Mine (EPA ID WAD980772789), California Gulch (EPA ID COD980717938), Blackbird Mine (EPA ID IDD980725832).

Note that it is likely, based on a review of mining and milling practices, that most if not all 29 non-operating sites reviewed generated tailings. Documentation specifically described tailings at seventeen sites, however.

[617] "National Priorities List Site Narrative: Gilt Edge Mine," Environmental Protection Agency. Accessed November 25, 2011 at: https://semspub.epa.gov/work/08/100000185.pdf.

Environmental Improvement Division inspected the site in 1980, 1982, and 1984, discovering the presence of cyanide and metals in the tailings piles themselves and in nearby soil and groundwater. The tailings also experienced surface drainage. Southwest ceased operations at the site in 1982 and declared bankruptcy in 1984.[618]

- The **Captain Jack Mill** (EPA ID COD981551427) is a Superfund site that incorporates the Big Five Mine, the White Raven Mine, and the Captain Jack Mill Works. Gold and silver mining activity at the site began in 1861 and continued intermittently through 1992. The Captain Jack Mill commenced operations in 1975, including the construction of tailings ponds. The EPA placed the site on the NPL in 2003 following the detection of antimony, arsenic, cadmium, copper, lead, manganese, thallium, and zinc in nearby Left Hand Creek. The primary source of contamination was AMD from the Big Five adit, which originated in the 19th century, although leaching and runoff were also detected originating from the Captain Jack tailings ponds constructed in the 1970s. Additionally, Paul Danio, an individual who operated the site in 1992, discharged mill tailings directly into Left Hand Creek before the Colorado Division of Minerals and Geology intervened.[619]
- The **Cyprus Tohono Mine** (EPA ID AZD094524097) is a surface copper mine located in Casa Grande, Arizona. Activity began at the site in 1881. In 2009, the mine was moved into "care and maintenance." The most recent operator was the Cyprus Tohono Corporation, a subsidiary of Freeport-McMoRan Copper and Gold, Inc., which took over the site in 1987. Cyprus Tohono Corporation expanded the extant surface mining activity and heap leach operations. In 2005, Cyprus Tohono Corporation began operating a solvent extraction/electrowinning circuit for processing heap leach solution. In 2000, EPA-initiated groundwater investigations uncovered elevated sulfate and uranium concentrations beneath the tailings impoundments. It is unclear when the impoundments were constructed.[620] Although copper operations continue at this mine, CERCLA

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[618] U.S. Environmental Protection Agency, *Decision Summary: Cimarron Mining Operation Site Operable Unit 1, Record of Decision* (Washington, DC: U.S. Government Printing Office, 1990); U.S. Environmental Protection Agency, *Decision Summary: Cimarron Mining Operation Site Operable Unit 2, Record of Decision* (Washington, DC: U.S. Government Printing Office, 1990); and "Online Site Description: Cimarron Mining Co.," Environmental Protection Agency. Accessed January 13, 2012: https://nepis.epa.gov/Exe/ZyNET.exe/20013XZ4.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C86thru90%5CTxt%5C00000015%5C20013XZ4.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.

[619] Colorado Department of Public Health and Environment, *Final Captain Jack Superfund Site Remedial Investigation and Risk Assessment Report* (22 May 2008).

[620] "Superfund Site: Cyprus Tohono Mine," U.S. Environmental Protection Agency, Region 9. Accessed December 14, 2015, at: http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/84e3d3f748094337882572300794f02/b3a939aef4ee637788257acb006a16ec!OpenDocument.

removal actions have addressed contamination from former tailings impoundments and process ponds.

Currently Operating Facilities

Documents confirmed the generation of tailings for least 31 of the 70 currently operating facilities reviewed.[621] Of those 31 sites, tailings were involved in releases or environmental contamination at eleven of the facilities. Activity at many of the facilities extended back before the widespread use or regulatory requirement of impoundments, liners, and other tailings containment strategies. Thus, many releases before 1995 were due to the direct discharge of tailings into the local environment or inadequate impoundment.

At nine of the 11 facilities, however, releases due to tailings occurred during or after the and the adoption of currently used tailings management practices.

- **ArcelorMittal Minorca** (MSHA ID 2102449) is an iron mining and processing facility located in Virginia, Minnesota. Mining at the site began in 1974 and an iron pellet processor was constructed at the site in 1977. Mittal Steel USA began operating the site in 2007. Three failures in the tailings and waste rock pipe and tailings dike at the site occurred in 2013 and 2014, discharging 8,500 cubic yards of tailings and waste rock and affecting 15.3 acres of wetlands, potentially destroying the area's ability to function as a natural aquatic habitat and filtration system. It is unclear when the tailings and waste rock pipe and impoundment were installed.[622]
- **Morenci** (MSHA ID 200024) is a surface copper mine, operated as a joint venture between Freeport (85 percent) and Sumitomo (15 percent) located in Morenci, Arizona. Activity at the site began in 1881. Currently, the site operates a crushed-ore leach pad and

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[621] ArcelorMittal Minorca (MSHA ID 2102449), Asarco Ray (MSHA ID 0200150), Asarco Silver Bell (MSHA ID 0200134), Buckeye Olive Creek (MSHA ID 5000304), Coeur Kensington (MSHA ID 5001544), Cyprus Tohono (MSHA ID 0202579), Florida Canyon Mine (MSHA ID 2601947), Freeport McMoRan Henderson (MSHA ID 0500790), Freeport McMoRan Morenci (MSHA ID 2000024), Hecla Greens Creek (MSHA ID 5001267), Kinross Crown Resources Buckhorn Mine (MSHA ID 4503615), Rio Tinto Kennecott Bingham Canyon (MSHA IDs 4200149 and 4201996), Robinson Nevada (MSHA ID 2601916), Simplot Smoky Canyon/Don (MSHA ID 1001590), Sixteen to One Mine (MSHA ID 401299), US Silver Galena (MSHA ID 1000082), Veris Gold Saval 4 – Jerritt Canyon (MSHA IDs 260742 and 2601621), CML Iron Mountain (MSHA IDs 4201927 and 4202624), Molycorp Mountain Pass (MSHA ID 402542), Barrick Goldstrike Mine/Mill/Roaster (MSHA IDs 2601089, 2602673, and 2602674), Energy Fuels White Mesa (MSHA ID 4201429), Freeport McMoRan Climax (MSHA ID 0502256), Materion Delta (No MSHA ID), Stillwater East Boulder (MSHA ID 2401879), Stillwater Stillwater/Columbus (MSHA ID 2401490), Freeport McMoRan Tyrone (MSHA ID 2900159), Nyrstar East Tennessee Complex-Young (MSHA ID 4000170), Rye Creek (MSHA ID 2402602), Salauro Tonopah (MSHA ID 2602718), Simplot Smoky Canyon/Don (MSHA ID 1001590), Mosaic South Pasture Hardee (MSHA ID 0800903), US Magnesium (No MSHA ID).

Note that it is likely, based on a review of mining and milling practices respective to tailings, that most if not all 70 of the current sites reviewed above generated tailings. We were only able to find documentation of tailings at the above 31 sites, however. Note, too, that Cyprus Tohono was part of both the non-operating site sample and the currently operating facility sample.

[622] "Enforcement and Compliance History Online: Case No. 05552000151009" and "Enforcement and Compliance History Online Case No. 0520151010," Environmental Protection Agency. Accessed December 10, 2015; "Pipeline, Storage Basin Failures Send Ore Tailings and Road Aggregate into Wetlands," Minnesota Pollution Control Agency, June 24, 2015. Accessed December 10, 2015, at: http://www.pca.state.mn.us/index.php/about-mpca/mpca-news/current-news-releases/pipeline-storage-basin-failures-send-ore-tailings-and-road-aggregate-into-wetlands-2-enforcement-actions-result.html; and "ArcelorMittal Pays Fines, Cleans Up," *Hibbings Daily Tribune* (26 June 2015).

stacking system, low grade run-of-mine leaching system, four solvent extraction plants, and three electrowinning tank houses. The facility transitioned from a smelting processing to solvent extraction/electrowinning in 1987. It is unclear when the site installed the tailings impoundments currently in use. In 2000 and 2001, it was discovered that rainwater ponds formed on the Morenci tailing impoundments were highly acidic and led to death and other injuries to migratory birds.[623]

- **Hecla Greens Creek** (MSHA 5001267) is a lead, zinc, silver, and gold underground mine located near Juneau, Alaska, and operated by the Hecla Greens Creek Mining Company. The mill produces 650,000 tons of tailings annually. Tailings are dewatered in a filtered press; half the tailings are mixed with concrete and hauled into the mine to serve as backfill, while half are placed in a disposal facility. In 2013, elevated concentrations of metals were detected in the snow and lichens adjacent to the tailings disposal facility. The USFS, who installed the lichen to act as a biomonitor of the recently expanded tailings facility, concluded the contamination was the result of fugitive dust emissions from the tailings.[624]
- The **Robinson Operation** gold and copper surface mine (MSHA ID 2601916) is operated by the Robinson Nevada Mining Company and located in White Pine County, Nevada. The facility processes its ore with a flotation circuit. In 1996, while the site was operated by BHP Copper subsidiary Magma Nevada Mining Company, five releases of copper flotation tailings solution containing sodium cyanide, a CERCLA hazardous substance under sections 102-103, occurred due to equipment failure; they ranged in size from 1,500 gallons to 66,000 gallons.[625] It is unclear when the tailings equipment was constructed. Four of the five spills resulted in soil contamination, and one spill contaminated a downstream drainage bed for 2.3 miles with an average flowpath of three feet.[626]
- The **U.S. Silver Galena mine** (MSHA ID 1000082) is a silver-lead and silver-copper underground mine located near Wallace, Idaho, and operated by the U.S. Silver Corporation since 2007. The mine sends tetrahedrite ore and galena-bearing ore to the Galena and Coeur mill facility; both use a flotation circuit to process the ore. In 2014,

[623] "Natural Resource Injury Case Settled for Freeport-McMoRan Morenci Mine," Arizona Department of Environmental Quality, Arizona Game and Fish Department, U.S. Fish and Wildlife Services, July 2, 2012. Accessed December 1, 2015: http://azgfd.net/artman/publish/NewsMedia/Natural-resource-injury-case-settled-for-Freeport-McMoRan-Morenci-Mine.shtml. See also "Morenci Mine Description," Freeport-McMoRan. Accessed December 10, 2015, at: http://www.fcx.com/operations/USA_Arizona_Morenci.htm.

[624] United States Department of Agriculture, Forest Service, *Greens Creek Mine Tailings Disposal Facility Expansion: Final Environmental Impact Statement and Record of Decision* (Washington, DC: U.S. Government Printing Office, 2013), Volume 1.

[625] For CERCLA status, see U.S. Environmental Protection Agency, EPCRA/CERCLA/CAA §112(r) Consolidated List of Lists (March 2015).

[626] U.S. Environmental Protection Agency, *Damage Cases and Environmental Releases from Mines and Mineral Processing Sites* (Washington, DC: U.S. Government Printing Office, 1997).

U.S. Silver Corporation signed a Consent Agreement and Final Order with EPA Region 10 admitting to discharging wastewater from the Osburn tailings pond into Lake Creek and the Coeur d'Alene River that carried excessive concentrations of mercury and copper in 2012 and 2013. The discharge was the result of a failure to monitor treated water normally discharged to water system. U.S. Silver also admitted that on March 14, 2014, it discharged tailings slurry directly into Lake Creek.[627]

- The **Veris Gold Jerritt Canyon Site** (MSHA ID 2602742; 2601621) is a gold mine located in Elko County, Nevada, first operated in 1980 and now operated by Queenstake Resources USA, Inc., a wholly owned subsidiary of Yukon-Nevada Gold Corporation. The site includes 12 closed surface mines (four reclaimed) and five underground mines. The facility processes the ore through crushing, roasting, carbon-in-leach with cyanidation and carbon adsorption, Merrill-Crowe process using zinc, and precipitate refining. Ore is sent to a lined tailings impoundment. In 1991, a Finding of Alleged Violation was issued because of a cyanide plume in the groundwater caused by seepage from the impoundment. In response, the facility installed a seepage collection system to pump any seepage back to the storage facility.[628] The tailings facility experienced additional releases of mercury due to a faulty seepage return line in 2013.[629]
- **Molycorp Mountain Pass** (MSHA ID 402542) is an open-pit lanthanide mine, beneficiation, and processing facility in Mountain Pass, California, currently operated by Molycorp and active since 1950. It processes its ore using bioleaching, a flotation process, and solid phase extraction. The facility now disposes of tailings as solid paste tailings in a dry stack facility, but the site houses old tailings ponds. On May 26, 1989, approximately 3,375 gallons spilled from a damaged pipeline carrying tailings water and effluent from the separation plant. The spill was contained in an on-site stormwater pond.[630]
- The **Energy Fuels White Mesa Mill** (MSHA ID 4201429) is a uranium milling and tailings disposal facility six miles south of Blanding, Utah. The tailing impoundments are four cross-valley dikes with embankments of native granular materials, lined with 30-millimeter PVC flexible membrane liners underlain with crushed sandstone; cells 2 and 3

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[627] U.S. Environmental Protection Agency, *Consent Agree and Final Order In the Matter of U.S. Silver – Idaho Inc., Coeur and Galena Mines and Mills, Wallace, Idaho*, effective 16 September 2014.

[628] Draft Report for E.P.A. Review: "Financial Responsibility Cost Estimate Review," August 10, 2012.

[629] Office of Resource Conservation and Recover. "Discharges from Hardrock Mines and Mineral Processors Operating in the Modern Mining Era (1978-Present)." September 29, 2016.

[630] U.S. Environmental Protection Agency, *Draft: Mining Waste Releases and Environmental Effects Summaries for the State of California* (Washington, DC: U.S. Government Printing Office, 1994. Note that Molycorp has changed the status of its Mountain Pass mine to "Care and Maintenance Mode" as of August, 2015. See "News Release: Molycorp to Move Its Rare Earth Facility to 'Care and Maintenance Mode,'" Globe News Wire, November 26, 2015. Accessed December 10, 2015, at: https://globenewswire.com/news-release/2015/08/26/763530/0/en/Molycorp-to-Move-Its-Mountain-Pass-Rare-Earth-Facility-to-Care-and-Maintenance-Mode.html.

have slime drainage systems. Tailings are in the form of a slurry, and the tailings cells are uncovered.[631] In 2015, the Utah Department of Environmental Quality discovered that radon emissions from the tailings cells exceeded by up to 80 times the limits established in the CAA for impoundments constructed before 1989,[632] even from the newly constructed cell 4. The investigation is ongoing.[633]

- The **Climax Molybdenum** open-pit mine (MSHA ID 0502256), located in Lake County, Colorado, has been active since 1918. Climax Molybdenum, a subsidiary of Freeport-McMoRan, currently operates the mine. The processing facility operates a flotation circuit. Flotation tailings are sent via pipelines to ponds, where sands settle out and water is decanted back to the mill for reuse. The decanting left a tailings "beach" in the impoundments. In 1986, the Colorado Mined Land Reclamation Board issued a Notice of Violation because it discovered that high winds had carried tailings dust from the impoundments and dam off-site. It is unclear when the impoundment was constructed.[634]

The sample of 70 currently operating facilities considered did not include an example of a release from phosphogypsum stacks. Additional research showed that on October 1, 2015, Mosaic Fertilizer, LLC agreed to an $8 million civil penalty to the United States, the State of Louisiana, and the State of Florida because of violations related to corrosive materials it disposed with its phosphogypsum stacks at Mosaic's New Wales, Bartow, and Riverview facilities in Florida, and its Uncle Sam facility in Louisiana.[635]

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[631] Utah Department of Environmental Quality, Ground Water Discharge Permit No. UGW370004, granted to Energy Fuels Resources (USA) Inc. for milling and tailings facility located approximately 6 miles, effective 24 August 2012.

[632] Limits from Clean Air Act National Emission Standards for Hazardous Air Pollutants, 40 C.F.R., Part 61, Subpart W. Note that those limits were set in 1989, no radon emission standards were set for new impoundments at the time.

[633] "Air Quality Board Meeting on Radon Emissions from White Mesa Uranium Mill Liquid Effluents," Utah Department of Environmental Quality, May 6, 2015. Accessed December 1, 2015: http://www.utah.gov/pmn/files/155851.pdf.

[634] U.S. Environmental Protection Agency, Office of Solid Waste, *Human Health and Environmental Damages from Mining and Mineral Processing Wastes* (Washington, DC: U.S. Government Printing Office, 1995).

[635] "Mosaic Fertilizer, LLC Settlement," U.S. Environmental Protection Agency, October 1, 2015. Accessed December 2, 2015, at http://www2.epa.gov/enforcement/mosaic-fertilizer-llc-settlement.

D. Leaks and Spills Resulting in Releases from Mining and Associated Processes

Mining and associated processes have an inherent potential for leaks and spills, which may result in releases. Many different commodities and process chemicals are used in hardrock mining activities, and often transport is required between subsequent processing steps, thus increasing the risk of releases. In addition, operators may use toxic process chemicals, increasing the potential for harm associated with these releases.

Documentation does not suggest that operational leaks and spills were major factors in the listing of non-operating Superfund sites, but these types of releases are documented as relatively common occurrences at currently operating facilities. From 1990-2014, over 2,000 spills at U.S. hardrock mining and mineral processing facilities were reported to the National Response Center.[636]

Operational spills and leaks occur during three main activities:

- leaks from process plants, which occur during the many processes used to purify and concentrate ore,
- leaks from equipment, which are generally not directly mining-related but are releases of chemicals and hazardous substances from machines used in the mining process, and
- leaks from transit, which occur when both ore and process chemicals are being transported to or between sites, processing operations and waste management facilities.

Sources of Spills and Leaks

All processing of ore, including physical and magnetic processing, can result in releases of intermediate material and waste. Ore must be transported from the extraction site to the processing facility. Process water and solutions are often stored in ponds on site for use and recycling. Slurries are piped from mill facilities to storage facilities (which can include waste management features such as tailings ponds) by pipeline, truck, or conveyor. The slurry, made up of ore and process chemicals, can contain mobilized contaminants and other hazardous substances. Based on reports to the National Response Center, equipment failure (e.g., pipe breaking, tank leakage) and human error are the most common reasons for these types of incidents.

Leaks also often occur due to liner failures, containment failures during transport or at exchange points (e.g., conveyor drop points or truck offloads), and defects in pipe seams. Operator error, such as mishandling of solutions (e.g., over-application) or equipment, and severe weather events that overwhelm containment systems can contribute to these types of leaks. Non-processing

[636] The National Response Center, maintained by the U.S. Coast Guard (and previously also by EPA), aggregates and publishes reported toxic chemical spills and other accidents. This database was previously referred to as ERNS. Reports, including incident and facility details, are published at: http://www.nrc.uscg.mil/.

equipment, such as excavation machinery and transport trucks, can also cause releases of petroleum products, lubricants, hydraulic fluid and other hazardous substances.[637]

Regulations Related to Leaks and Spills

Federal agencies and most states have developed regulations specific to chemical spills under emergency management and accident prevention frameworks.

The Emergency Planning and Community Right-to-Know Act (EPCRA) Emergency Release Notification Requirements dictate that any accidental chemical release exceeding the applicable minimal reportable quantity must be reported to the State Emergency Response Commissions (SERCs) and the National Response Center. The facility must also provide written follow-up information afterwards and information about the release must be available to the public.[638] The National Response System, which is informed by the National Oil and Hazardous Substances Pollution Contingency Plan, Clean Water Act, and CERCLA helps coordinate the response to such events. According to National Response Center information, most reported incidents are handled by the operator on-site, but in some cases, state or federal officials are involved in the response effort.

Legal protocols exist to ensure proper handling and on-site response to prevent and mitigate accidental releases. For example, under the BLM's 43 CFR Subpart 3809, a spill contingency plan is required for every Plan of Operations that involves chemical processing or the use or storage of hazardous substances.[639] These plans must describe what measures an operator will take to avoid releases of chemicals or hazardous substances including transport, storage, handling and disposal as well as how an operator will respond to a release, including containment and clean-up procedures, enhanced monitoring measures and notification procedures to the appropriate regulatory agencies.

States also have programs to prevent and respond to releases and can also impose their own notification and inspection requirements. Alaska's Department of Environmental Conservation, for example, administers their Spill Prevention and Response program, which includes a risk reduction program for underground storage tanks and spill prevention education and technical assistance.

Evidence from Contemporary Mining and Processing Facilities

The National Response Center maintains records of the chemical releases and accidents in the United States that are reported to them. While releases occur relatively frequently, little information is available about long-term outcomes. As a result, the ultimate harm caused by operational spills and releases is difficult to quantify.

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[637] Petroleum is specifically excluded as a CERCLA hazardous substance, so is not subject to CERCLA response authority and liability.

[638] EPCRA Section 304.

[639] 43 CFR 3809.401(b)(2)(vi).

From 1990-2014, 2,040 incidents were reported at hardrock mining and mineral processing facilities, with 63 percent of reported incidents originating from process equipment, tanks, or pipes. The most frequent causes of reported incidents include equipment failure (54.4 percent) and employee error (14.6 percent). Only 5.4 percent of incidents were a result of severe weather events or other natural phenomena. Relatively few reported incidents were the result of transport accidents or illegal dumping.[640]

ERNS reports contain limited information about cleanup or enforcement actions taken after facility notification, and suggest that most spills are handled by the operator on-site. Local authorities were notified for approximately 15 percent of incidents. Roughly 17 percent of incidents involved spills of one of the ten highest-ranked hazardous substances of concern.[641]

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[640] Releases of CERCLA hazardous substances associated with transportation may also be within the jurisdiction of Department of Transportation regulations.

[641] Pursuant to CERCLA Section 104(i), the EPA and the Agency for Toxic Substances and Disease Registry (ATSDR) develop a biennial Substance Priority List (SPL) that ranks substances most commonly found at Superfund National Priority List (NPL) facilities and which are determined to pose the most significant potential threat to human health. Rankings reflect frequency, toxicity, and potential for human exposure at NPL sites. Although the SPL reports a toxicity score, this measure is categorical rather than linearly ordered. Toxicity and overall SPL ranking are highly correlated, however. ATSDR assigned seven of the top 10 SPL substances the highest toxicity score, while the other three were associated with the second highest toxicity category. See: "Priority List of Hazardous Substances," Agency for Toxic Substances & Disease Registry. Accessed January 20, 2015, at: http://www.atsdr.cdc.gov/spl/.

Appendix I: Summary of Approach Used to Generate a Sample of Non-Operating Sites

This document discusses the approach EPA applied to generate a sample of non-operating CERCLA sites to be researched and reviewed. It also briefly summarizes the distribution of sites in the sample across commodity groups, geographical location, and operations type.

Relevant information for the non-operating sites will be collected on a sample, or incremental, basis, recognizing that "knowing more" about a smaller sample of these sites may be more valuable than "knowing less" about all of the sites. Thus, EPA developed the sample of non-operating sites across commodity groups to include the sites with more robust operational and risk data. EPA also identified the non-operating sites for which data have been previously collected.

Steps Taken to Identify and Review the Sites within the Proposed Site Sample

The proposed sample of sites (29 in total) represents 28 percent of all sites within the non-operating CERCLA universe (102 in total). The list below summarizes the steps taken to generate the non-operating site sample:

- Identify the sites within the current version of the non-operating universe for which risk data were previously collected or an attempt was made to collect those data: 31 sites total.
- Identify the sites within the current version of the non-operating universe which were previously included on EPA's lists of response action sites that met certain EPA criteria (i.e., response action occurred, site met EPA's 2012 definition of mine or processor, contamination from onsite). Limited operating data have been collected for these sites (89 sites total).
- Match the non-operating universe's commodity group categories to commodity group categories within the currently operating universe. Remove sites within the "mixed" non-operating commodity groups that include multiple commodity groups (e.g., "Mixed: More Than Three Commodities [including Radioactives]"). Note, the analysis excludes "mixed commodity group" sites that mined or processed commodities from more than three commodity groups. This is necessary in order to isolate the operational and risk data associated with specific commodity groups and collect useful data that would allow ultimate comparisons with the facilities in the same commodity groups within the currently operating universe.
- Review the distribution of sites within the resulting sample of the non-operating sites (sites for which the three criteria described in steps 2, 3, and 4 above are true – 27 sites total) and compare this distribution to the distribution of facilities by commodity group and type of operation (mine/processor) within the currently operating universe.

- For commodity groups that appeared under-represented (one site per commodity group), review the non-operating universe data to determine whether additional sites could be included in the sample.
- The following commodity groups only have a single site each within the non-operating universe: “Mixed: Aluminum & Ferrous Metals & Non-Ferrous Metals,” “Mixed: Ferrous Metals & Non-Ferrous Metals,” and “Rare Earth Minerals.” The three sites in these commodity groups were included in the proposed non-operating sample.
- For Phosphate and Radioactive Metals commodity groups, review the data to manually select an additional mine site to increase the representation of mines within the sample:
- For Phosphates, EPA selected the additional mine on the non-operating site list that appeared to have the most data available (NAICS[642] codes, operations start and end date, ATSDR Public Health Assessment available) [Coronet Industries, FLD001704741]
- For Radioactive Metals, EPA selected the only remaining mine on the non-operating site list that had a Final NPL status [Westlake Landfill OU2, MOD079900932]

The above process resulted in a total of 29 sites within the proposed non-operating sample, out of 102 sites within the non-operating universe.

Summary of the Proposed Non-Operating Site Sample

Exhibit I.1. at the end of this memorandum summarizes the distribution of sites within the sample by commodity group and type of operation, and compares it to the distribution of sites within the currently operating universe. Exhibit I.2. provides a summary of locations of sites within the proposed non-operating sample.

As Exhibit I.1. shows, each commodity group is adequately represented within the proposed non-operating sample relative to the currently operating facilities list. While several groups may be relatively over-represented (phosphates, radioactive metals, and mixed: industrial rocks and non-ferrous metals groups), this occurs because of the low total number of sites within these groups.[643] Where the groups are under-represented with a single site in the universe, this occurs due to the fact that only a single site within this commodity group exists within the non-operating universe.

[642] North American Industry Classification System (NAICS)

[643] EPA aimed to include at least three sites within the proposed non-operating sample for each commodity group where the total number of sites within the non-operating universe allowed this.

Of the 29 sites within the proposed sample, 26 sites are on the NPL (as Final, Proposed, or Deleted sites) and three sites are not on the NPL. Removal actions have occurred at 20 sites; eight sites did not have removal actions. Removal action information is not provided for one site.

At this time, EPA is unable to determine the distribution of geological/hydro-geological features within the proposed site sample because there are no such data readily available for the sites within the non-operating universe. Finally, none of the sites within the proposed non-operating sample are known to have conducted sand and/or gravel mining prior to waste disposal.

Exhibit I.3. summarizes the distribution of individual commodities for all sites within the non-operating universe, for the currently regulated universe, and for the proposed sample of 29 non-operating sites. The distribution of commodities within the non-operating universe varies from that within the currently regulated universe. For example, gold was one of the commodities mined/processed at 31 percent of non-operating sites; the same value for the currently operating universe is 46 percent.[644] As another example, 26 percent of non-operating sites mined/processed silver; silver is the primary commodity for only 2 percent of facilities within the currently operating universe.

Emphasis was placed on selecting more recently active and listed NPL sites. These sites, with more recent operational and listing dates, were given priority so the collected risk related data is reflective of more current remedial technologies and mitigation practices. A modification of site selection criteria was required, in which EPA decided to only include sites with available ROD summaries (provided by EPA) in order to accelerate data abstraction in the limited time frame.

Conclusion

This analysis relied on a subset of sites for which risk data have already been collected, and to which EPA (subject to data availability and resource limitations): (a) further supplemented the risk data for the subset of sites; (b) attempted to collect similar information for sites which have not been previously reviewed; and (c) filled out operational and other information as necessary.

[644] Each facility within the currently operating universe includes information on a single commodity mined/processed. The majority of non-operating sites list multiple commodities mined/processed. Further research will be necessary to identify the primary commodity mined/processed at each non-operating site (if any).

Exhibit I.1. Summary of Proposed Non-Operating Site Sample with Representativeness in Currently Operating Universe

Combined Commodity Categories	Proposed Non-Operating Site Sample					Currently Operating Universe				Notes
	# Sites	# Sites, % Total	# Mines	# "Other"	# "Pilot Sites"	# Facilities in Comparable Commodity Group	% Facilities in Comparable Commodity Group	# Mines	# Processors	
Mixed: Aluminum & Ferrous Metals & Non-Ferrous Metals	1	3%	0	1	0	21	5%	5	16	- The single site in the non-operating universe that mentions "Aluminum" specifically - A potential commodity group match for "Aluminum and Ferrous Metals" groups in the currently operating universe
Mixed: Ferrous Metals & Non-Ferrous Metals	1	3%	0	1	1	37	9%	27	10	- The single site in the non-operating universe with "Ferrous Metals" - A match for "Ferrous Metals" group in the currently operating universe
Mixed: Industrial Rocks & Non-Ferrous Metals	3	10%	2	1	2	25	6%	21	4	A match for "Industrial Rock" group in the currently operating universe
Non-Ferrous Metals	15	52%	7	8	8	312	72%	263	49	
Phosphates	4	14%	1	3	3	17	4%	11	6	
Radioactive Metals	4	14%	2	2	2	12	3%	11	1	
Rare Earth Minerals	1	3%	0	1	1	11	3%	5	6	The single site in the non-operating universe in this commodity category
Total:	**29**	**100%**	**12**	**17**	**17**	**435**	**100%**	**343**	**92**	

Exhibit I.2. Summary of Proposed Non-Operating Site Sample by Location

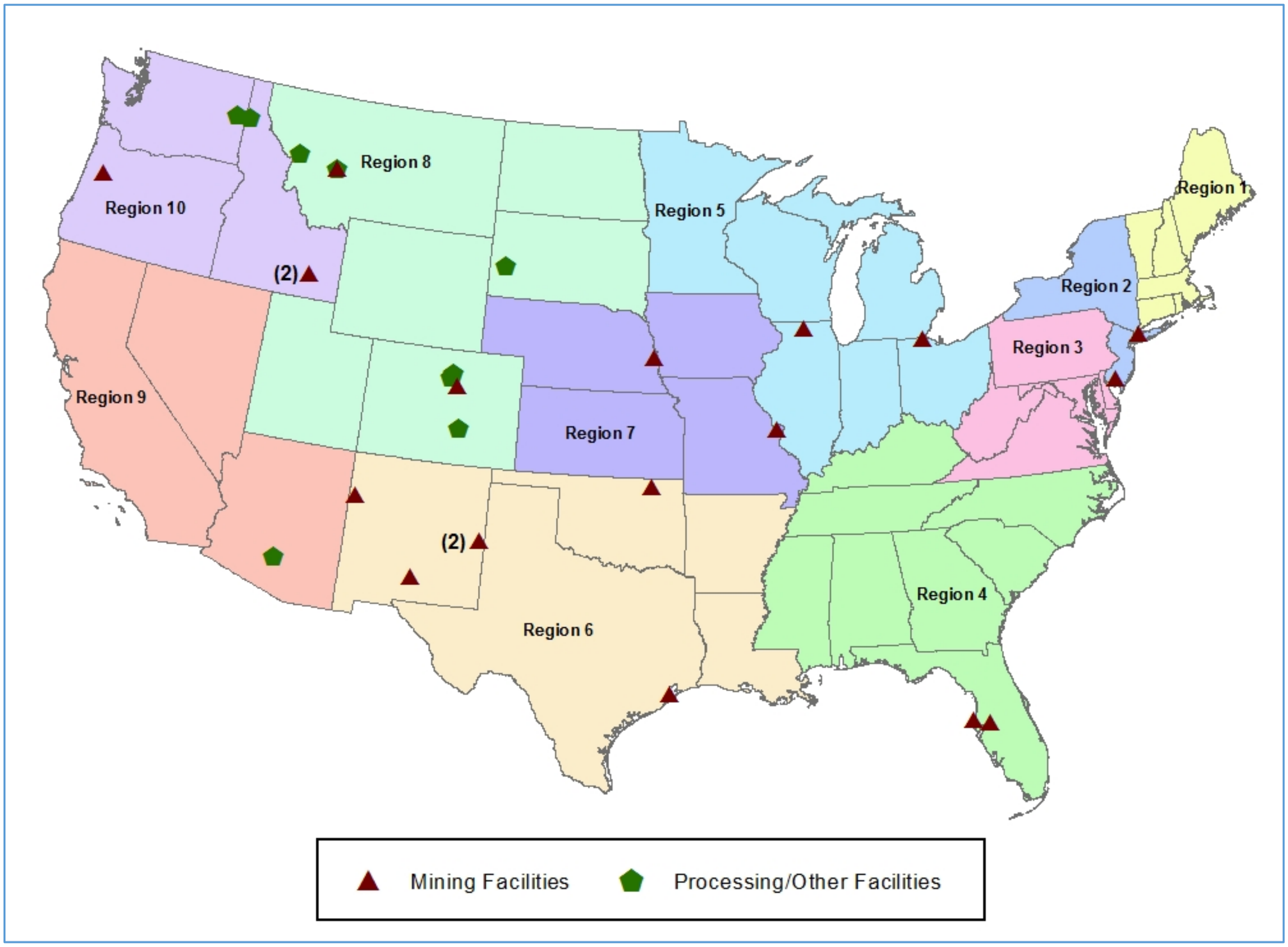


Exhibit I.3. Summary of Proposed Non-Operating Site Sample by Commodity Compared to Currently Operating Universe

Commodity Counts	Non-Operating Universe		Currently Operating Universe		Proposed Non-Operating Sample	
	# Sites	# Sites as a % of Total	# Sites	# Sites as a % of Total	# Sites	# Sites as a % of Total
Gold	32	31%	201	46.2%	8	28%
Silver	27	26%	7	1.6%	7	24%
Copper	24	24%	48	11.0%	7	24%
Lead	20	20%	8	1.8%	5	17%
Zinc	18	18%	7	1.6%	5	17%
Phosphorus or Phosphate	17	17%	17	3.9%	5	17%
Uranium	13	13%	12	2.8%	3	10%
Sulfur/Sulfuric Acid	8	8%	0	0%	2	7%
Molybdenum	6	6%	14	3.2%	1	3%
Vanadium	5	5%	0	0%	1	3%
Antimony	5	5%	3	0.7%	3	10%
Arsenic	4	4%	0	0%	1	3%
Limestone	4	4%	0	0%	0	0%
Tungsten	4	4%	1	0.2%	2	7%
Fluorspar or Fluorite, Fluoride Compounds	3	3%	1	0.2%	1	3%
Sodium Metal or Compounds	3	3%	0	0%	1	3%
Bismuth	2	2%	0	0%	2	7%
Cadmium	2	2%	1	0.2%	2	7%
Clay	2	2%	0	0%	0	0%
Cobalt	2	2%	1	0.2%	2	7%
Iron	3	3%	38	8.7%	1	3%
Gravel	2	2%	0	0%	1	3%
Magnesium	2	2%	1	0.2%	0	0%
Niobium	2	2%	0	0%	2	7%
Platinum	2	2%	3	0.7%	1	3%
Precious Metals	2	2%	0	0%	0	0%
Pyrite	2	2%	0	0%	1	3%
Quartz	2	2%	0	0%	1	3%
Radium	2	2%	0	0%	0	0%
Sand	2	2%	0	0%	1	3%
Tantalum	2	2%	0	0%	1	3%
Tin	2	2%	0	0%	2	7%
Thorium	2	2%	0	0%	0	0%

Commodity Counts	Non-Operating Universe		Currently Operating Universe		Proposed Non-Operating Sample	
	# Sites	# Sites as a % of Total	# Sites	# Sites as a % of Total	# Sites	# Sites as a % of Total
Aluminum	1	1%	10	2.3%	1	3%
Asbestos	1	1%	0	0%	0	0%
Chalcopyrite	1	1%	0	0%	1	3%
Chlorine	1	1%	0	0%	1	3%
Chromium and Compounds	1	1%	1	0.2%	1	3%
Columbium	1	1%	0	0%	0	0%
Galena	1	1%	0	0%	1	3%
Hafnium	1	1%	0	0%	1	3%
Indium	1	1%	2	0.5%	1	3%
Lepidolite	1	1%	0	0%	0	0%
Lithium	1	1%	2	0.5%	0	0%
Manganese	1	1%	0	0%	0	0%
Nickel	1	1%	0	0%	1	3%
Rare Earths	1	1%	4	0.9%	1	3%
Rhenium	1	1%	0	0%	0	0%
Silica	1	1%	0	0%	0	0%
Steel	2	2%	0	0%	1	3%
Tetrahedrite	1	1%	0	0%	0	0%
Tellurium	1	1%	1	0.2%	1	3%
Thallium	1	1%	0	0%	1	3%
Titanium	1	1%	4	0.9%	1	3%
Zirconium	1	1%	4	0.9%	1	3%
Alumina	0	0%	4	0.9%	0	0%
Barite Barium Ore	0	0%	10	2.3%	0	0%
Bauxite	0	0%	7	1.6%	0	0%
Beryllium	0	0%	3	0.7%	0	0%
Boron	0	0%	5	1.1%	0	0%
Brucite	0	0%	2	0.5%	0	0%
Germanium	0	0%	5	1.1%	0	0%
Potash	0	0%	8	1.8%	0	0%
Total:			**435**	**100%**		

Appendix II: Summary of Approach Used to Generate a Sample of Currently Operating Universe

This document summarizes the proposed methodology to select a sample of hard rock mining and processing (HRM/P) facilities in the currently operating universe to be further researched and reviewed.

EPA will collect relevant information about releases of hazardous substances for a sample of facilities in the currently operating universe on a sample, or incremental, basis, recognizing that "knowing more" about a smaller sample of these facilities may be more valuable than "knowing less" about all of the facilities. Given the need for a cost-effective and timely data collection effort, EPA has chosen a sample of currently operating facilities across commodity groups, commodities, and facility types that is intended to be generally representative of the entire currently operating universe.

Steps Taken to Select Facilities within the Currently Operating Universe

The methodology for selecting facilities for the sample of currently operating facilities is described as follows:

1. Use the list of 435 currently operating facilities plus a list of 12 currently operating steel mills that use blast furnaces.[645,646]
2. Keep only records for facilities whose operating status (as of October 2014) is "active" (299 facilities). This eliminates facilities whose operating status is "temporarily idled" (46 facilities) or "intermittent operation" (102 facilities).
3. From the subset of 299 facilities, select the number of facilities with a given set of characteristics to include in the sample (with the goal of generating a reasonable final sample size with a wide representation of individual commodities well as facility types for further research) as follows: [647]

[645] The list of currently operating facilities may change based on periodic updates of these data.

[646] Processors in this list of currently operating facilities have been included based on a definition of processors that is subject to refinement. EPA currently defines "*mineral processing*" as the sequence of activities following extraction and/or beneficiation of metallic or non-fuel non-metallic minerals to: (1) separate and concentrate a target metallic or non-fuel non-metallic mineral from the ore, and (2) to refine ores or mineral concentrates to extract a target metallic or non-fuel non-metallic material. Mineral processing includes the mechanical, thermal, electrical, and/or chemical treatment of naturally occurring earthen materials, either solid or liquid (e.g., rock, ore, mineral or extracted subsurface brine) to recover, purify or create a final mineral product (e.g., dimension stone expanded vermiculite, or refractory clay) or a feedstock of sufficient purity that it can then be used in further industrial or manufacturing operations (e.g., sintered iron pellets, copper concentrates, or phosphoric acid).

[647] This approach focuses primarily on providing a comprehensive sampling of commodities and facility types, rather than geographic locations. It also yields a broad geographic distribution of facilities, however, as shown in Exhibit II.2.

a. If there are two or fewer facilities representing a single commodity / facility type, include the single facility or both facilities in the sample. This ensures that the sample reflects the broadest possible range of site characteristics.

b. If there are fewer than six facilities representing a single commodity, include at least two mines and two processors in the sample. This ensures that the sample reflects a mix of mines and processors across all commodities.

c. For all other commodities / facility types, apply the following rule to select the facilities in the sample: include the larger of three facilities or $\frac{T}{7}$ facilities in the sample, where T is the total number of facilities for a unique commodity / facility type combination. This ensures that the sample more closely reflects the distribution of facilities in the entire currently operating universe.

4. Across each commodity / facility type, select the designated number of facilities from Step 3, subject to the following:

   a. When sampling among "active" facilities, first select facilities on EPA's list of "pilot" sites,648 since certain data have likely already been collected for these facilities.

   b. Next, select among the subset of facilities matched by RTI to the V9 "currently active" list **AND** for which EPA has collected program data (i.e., TRI, DMR[649], National Emissions Inventory [NEI], Biennial Reporting System [BRS] and Total Maximum Daily Load [TMDL] analysis).[650]

   c. Then, select among the remaining facilities (including those that are not on the V9 list).

The above process results in a sample of 111 facilities within the currently operating universe.

Summary of the Proposed Currently Operating Universe Sample

The final sample (111 facilities) represents approximately 25 percent of all facilities in the currently operating universe (447 facilities). Exhibits II.1a. through II.1c. summarize the distribution of facilities within the sample by commodity group, facility type, and commodity and compare it to the distribution of facilities within the entire currently operating universe. Exhibits II.1a. and II.1b. show that each commodity group and facility type is adequately represented within the proposed sample relative to distribution of facilities in the currently

[648] Pilot sites are sites in the non-operating universe for which additional case studies were conducted by RTI, as summarized in the Final Report prepared by RTI entitled, "108(b) Risk Assessment Data Support, Data Collection for Hard Rock Mining Sites," dated December 31, 2010 (RTI WA 1-20, Task 2-1) and in subsequent documents.

[649] Discharge Monitoring Report (DMR)

[650] Based on RTI's data collection under RTI WA 2-19, Task 2, there are 247 V9 sites in the currently operating universe and EPA has collected program data for 234 of these sites (including 197 active sites).

operating universe. As Exhibit II.1c. shows, the proposed sample includes 31 unique commodities and represents a mix of mines and processors. In the proposed sample, several commodities may be over-represented (e.g., alumina, bauxite, lithium, rare earth ores) because of the low total number facilities within these groups. Other commodities may be under-represented (e.g., gold and copper) since the currently operating universe is heavily dominated by these facilities. This decision was made to ensure the proposed sample included a broader range of commodities.

Exhibit II.2. shows the location of facilities in the proposed sample. As the exhibit shows, the proposed sample includes facilities located in 31 states (out of a total of 38 states for the entire currently operating universe). The sample does not include any facilities located in the following states that have mining or processing facilities: West Virginia, South Dakota, Kansas, Mississippi, Nebraska, Illinois, or Alabama.

Overall, the sample includes 91 facilities which are on the V9 list and for which EPA has collected program data. There are also 3 facilities in the sample on the V9 list for which EPA has not collected program data and 17 facilities that are not on the V9 list.

Note that there are eight facilities in the currently operating universe that are pilot sites (or co-located with pilot sites). Of these, seven are included in the sample of currently operating facilities, while one is excluded because its operating status indicates it is an "intermittent operation."

Conclusion

To summarize, this effort (a) collected new data or further supplement existing data for a subset of facilities in the currently operating universe and (b) filled out operational and other information as necessary.

Exhibit II.1a. Summary of Proposed Sample of Currently Operating Facilities by Commodity Group

COMMODITY GROUP	# OF FACILITIES	% OF SAMPLE	% OF TOTAL UNIVERSE
Aluminum	10	9%	5%
Ferrous Metals	9	8%	11%
Industrial Rock	14	13%	6%
Non-Ferrous Metals	58	52%	70%
Phosphates	6	5%	4%
Radioactive Metals	4	4%	3%
Rare Earth Minerals	10	9%	2%
TOTAL	111	100%	100%

Exhibit II.1b. Summary of Proposed Sample of Currently Operating Facilities by Facility Type

FACILITY TYPE	# OF FACILITIES	% OF SAMPLE	% OF TOTAL UNIVERSE
Processing/Refining	47	41.4%	20.6%
Processing/Refining (Blast Furnace)	3	2.7%	2.7%
Surface Mine	34	30.6%	56.8%
Underground Mine	21	18.9%	16.6%
ISL / Solution Mine	3	2.7%	2.5%
Brine Extraction	3	2.7%	0.7%
Solar Evaporation	1	0.9%	0.2%
TOTAL	111	100%	100%

Exhibit II.1c. Summary of Proposed Sample of Currently Operating Facilities by Commodity

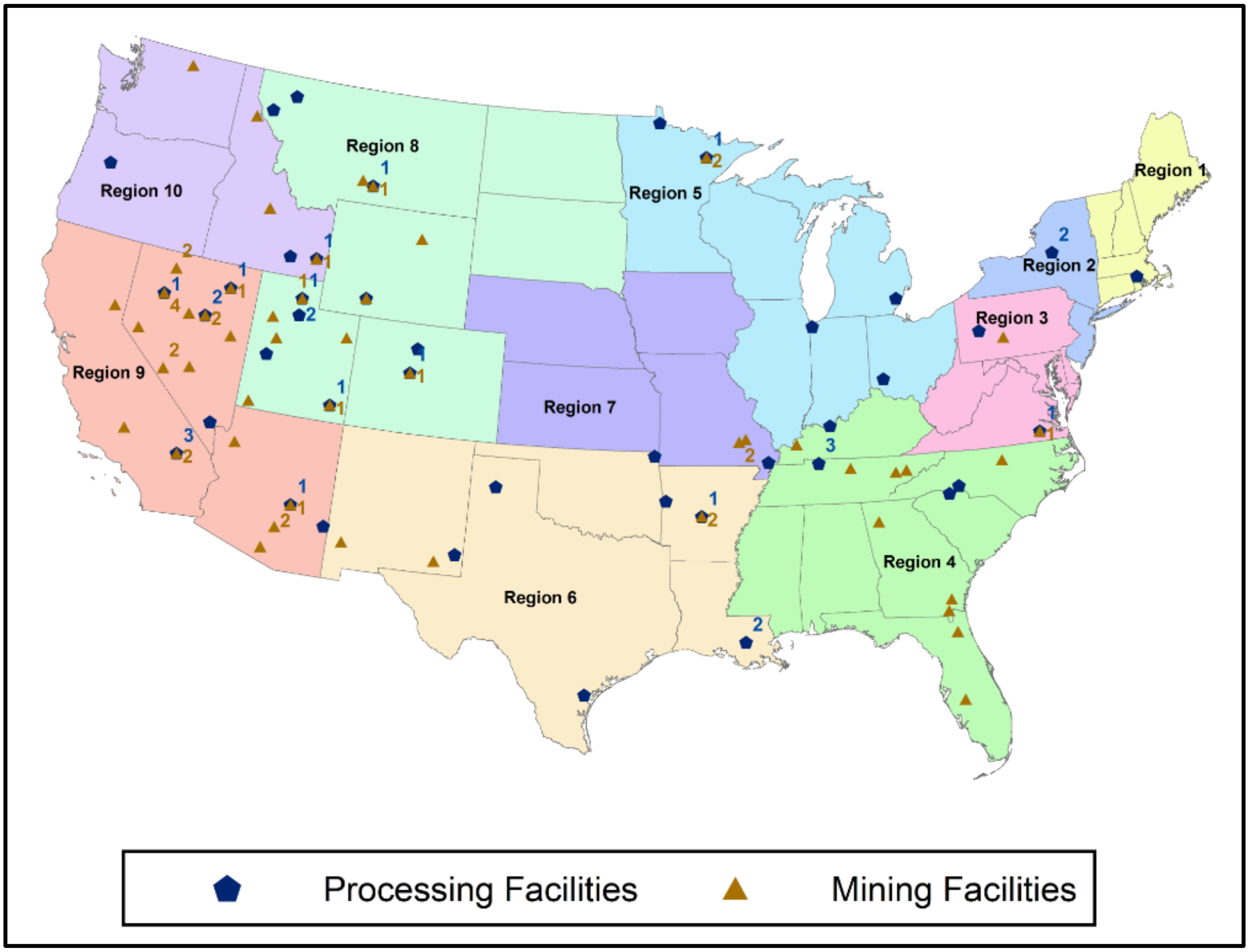
COMMODITY	MINE OR PROCESSOR	# OF FACILITIES	% OF SAMPLE	% OF TOTAL UNIVERSE
Alumina	Processor	2	1.8%	0.9%
Aluminum	Processor	3	2.7%	2.3%
Antimony	Mine	1	0.9%	0.2%
	Processor	2	1.8%	0.5%
Barite Barium Ore	Mine	3	2.7%	2.3%
Bauxite	Mine	3	2.7%	1.1%
	Processor	2	1.8%	0.5%
Beryllium	Mine	1	0.9%	0.2%
	Processor	2	1.8%	0.5%
Boron	Mine	2	1.8%	0.5%
	Processor	3	2.7%	0.7%
Brucite	Mine	1	0.9%	0.2%
	Processor	1	0.9%	0.2%
Cadmium	Processor	1	0.9%	0.2%
Chromite Chromium Ore	Mine	1	0.9%	0.2%
Cobalt	Processor	1	0.9%	0.2%
Copper	Mine	5	4.5%	7.4%
	Processor	3	2.7%	3.7%

COMMODITY	MINE OR PROCESSOR	# OF FACILITIES	% OF SAMPLE	% OF TOTAL UNIVERSE
Fluorspar	Mine	1	0.9%	0.2%
Germanium	Processor	3	2.7%	1.1%
Gold	Mine	10	9.0%	44.1%
	Processor	3	2.7%	2.1%
Indium	Processor	2	1.8%	0.5%
Iron Ore	Mine	3	2.7%	6.2%
	Processor	3	2.7%	2.5%
	Processor/Blast Furnace	3	2.7%	2.8%
Lead-Zinc Ore	Mine	3	2.7%	1.8%
Lithium	Mine	1	0.9%	0.2%
	Processor	1	0.9%	0.2%
Magnesium	Mine	1	0.9%	0.2%
Molybdenum	Mine	3	2.7%	1.6%
	Processor	3	2.7%	1.6%
Phosphate Rock	Mine	3	2.7%	2.5%
	Processor	3	2.7%	1.4%
Platinum Group Ore	Mine	2	1.8%	0.7%
Potash	Mine	3	2.7%	1.6%
	Processor	1	0.9%	0.2%
Rare Earths Ore	Mine	2	1.8%	0.5%
	Processor	1	0.9%	0.5%
Selenium and Tellurium	Processor	1	0.9%	0.2%
Silver Ore	Mine	3	2.7%	1.6%
Titanium	Mine	2	1.8%	0.7%
	Processor	1	0.9%	0.2%
Tungsten[651]	Mine	0	0.0%	0.2%
Uranium	Mine	3	2.7%	2.5%
	Processor	1	0.9%	0.2%
Zinc	Mine	3	2.7%	1.4%
	Processor	1	0.9%	0.2%
Zirconium and	Mine	2	1.8%	0.5%

[651] No tungsten facilities are included in the sample because there are no active facilities in the currently operating universe. The one mine producing this commodity is listed as an intermittent operation.

COMMODITY	MINE OR PROCESSOR	# OF FACILITIES	% OF SAMPLE	% OF TOTAL UNIVERSE
Hafnium	Processor	2	1.8%	0.5%
Sub-total: Mines		62	55.9%	78.9%
Sub-total: Processors		49	44.1%	21.1%
TOTAL		111	100.0%	100.0%

Exhibit II.2. Summary of Proposed Sample of Currently Operating Facilities by Location[652]



[652] The proposed sample includes two Alaska mines that are not shown on the map; the sample of currently operating facilities includes 70 mines and processors, when small mines and placer mining operations are excluded.

Appendix III: Proposed Data Collection Process for Non-Operating Sites and Currently Operating Facilities

As further described below, this effort will first aggregate information from a variety of EPA sources, including data and documentation already collected for CERCLA 108(b), and then supplement this information with data collection from additional sources as time permits. Effort will be made to collect the maximum number of data points within the time allotted. Exhibits III.1. and III.2. describe the proposed data elements for information collection for non-operating sites and currently operating facilities. The data will be aggregated in an Excel Workbook.

Relevant information for the currently operating facilities and non-operating sites will be collected on a sample, or incremental, basis, recognizing that "knowing more" about a smaller sample of these sites may be more valuable than "knowing less" about all of the sites. Appendices III.1 and III.2 include lists of the non-operating and currently operating site/facility samples, for which this effort will collect data.

The proposed data collection process for each site or facility in the sample is as follows:

1. Pull existing data elements from the CERCLA 108(b) comprehensive database and from the Lines of Evidence document, appendices, and supporting databases (dated June 9, 2014).
2. If a particular data point is not available, move on to the next data point. Rely on the existing information, where available.
3. Prioritize the search for information by relying on the following documents, in the following order:

ORDER	NON-OPERATING SITES	CURRENTLY OPERATING FACILITIES
1	ROD documents	Currently operating universe spreadsheet provided by Bill Kline (EPA)
2	RI/FS Data	Envirofacts (BR, CERCLIS, ECHO[653], FRS,[654] ICIS RCRAInfo, TRI)
3	Envirofacts (BR, CERCLIS, ECHO, FRS, Integrated Compliance Information System [ICIS] RCRAInfo, TRI)	ERNS incident reports provided by Bill Kline (EPA)
4	General research and outside sources (*e.g.*, 2012 Earthworks Copper Porphyry Mines report)	Kuipers cost model database
5	N/A	Dun & Bradstreet / Moody's
6	N/A	General research and outside sources (e.g., company websites, news sources)

- For data elements that require further explanation, or for which additional information is available, use comment fields (a column in the Excel worksheet).
- If possible, summarize information across operable units (OUs) at a site/facility.

While effort will be made to populate all of the proposed data fields, for non-operating sites, less emphasis will be placed on the "concentration of hazardous substance released" and "neighboring facilities contributed to the release" data elements.

Exhibit III.1. Proposed Data Elements to Be Collected – Non-Operating Sites

DATA ELEMENTS	PREVIOUSLY COLLECTED FOR SOME SITES	COMMENT	PROPOSED PRIMARY DOCUMENT	DOCUMENTS LIKELY TO CONTAIN PROPOSED DATA ELEMENT INFO
SITE INFORMATION				
Site name	✓		ROD	ROD Summaries
CERCLIS ID	✓		ROD	ROD Summaries
Latitude/longitude	✓	If available.	Envirofacts/FRS	
City, County, State	✓		Envirofacts/FRS	
Operation dates	✓		ROD	

[653] Enforcement and Compliance History Online (ECHO)

[654] Facility Registry System (FRS)

DATA ELEMENTS	PREVIOUSLY COLLECTED FOR SOME SITES	COMMENT	PROPOSED PRIMARY DOCUMENT	DOCUMENTS LIKELY TO CONTAIN PROPOSED DATA ELEMENT INFO
Description of operations	✓		ROD RI/FS	ROD Summaries HRM Site Characteristics Summaries – Minerals and Processes RI/FS Database or CERCLIS-
Commodities	✓		ROD RI/FS	ROD Summaries HRM Site Characteristics Summaries – Minerals and Processes RI/FS Database or CERCLIS
Mine/processor	✓	May be both or may be unknown. This element will have an associated comment field. EPA to provide the current definition of "processor".	ROD	ROD Summaries
If processor, proximity to mine		Does not reflect various methods of transporting materials between mine and processor. This element will have an associated comment field.	ROD	ROD documents, Permit documents, General research
NAICS code	✓	If available. May not be reported in ROD, or may need to be converted from SIC code. This element will have an associated comment field.	ROD RI/FS	ROD Summaries HRM Site Characteristics Summaries – Minerals and Processes RI/FS Database or CERCLIS
If mine, type of mining (open-pit, underground, etc.)	✓		ROD	
REGULATORY STATUS				
Subject to RCRA at time of release	✓	May not be reported in ROD.	ROD	ROD documents, Envirofacts
Subject to CWA at time of release	✓		ROD	ROD documents, Envirofacts
Subject to CAA at time of release			ROD	ROD documents, Envirofacts
Subject to SDWA (UIC program) at time of release			ROD	ROD documents, Envirofacts

DATA ELEMENTS	PREVIOUSLY COLLECTED FOR SOME SITES	COMMENT	PROPOSED PRIMARY DOCUMENT	DOCUMENTS LIKELY TO CONTAIN PROPOSED DATA ELEMENT INFO
Subject to state mining regulations at time of release			ROD	ROD documents, State environmental databases
Under BLM or USFS land use regulations			ROD	ROD documents, BLM LR2000 Land Patents Records
Under other federal oversight (NRC/DOE, etc.)				General research
PROCESS, WASTE MANAGEMENT, AND RELEASE INFORMATION				
CERCLA hazardous substance released	✓		ROD RI/FS	ROD Summaries COC Human Health Risk Summaries COC Eco Risk Summaries RI/FS Database or if needed, CERCLIS EPA Regional Office-
Amount released	✓		ROD RI/FS	ROD Summaries COC Human Health Risk Summaries COC Eco Risk Summaries RI/FS Database or if needed, CERCLIS EPA Regional Office-
Concentration of hazardous substance released	✓	Aggregate the data already available for the non-operating sites in the sample. Do not attempt collection of additional data for "new" sites (unless readily available in the ROD).	ROD	
Media affected (e.g., groundwater, surface water, air, soil, etc.)	✓		ROD RI/FS Baseline Risk Assessment (BRA)	ROD Summaries NPL Mining/Mineral Processing Summary RI/FS database or CERCLIS EPA Regional Office
AMD present?	✓	If specified in the ROD.	ROD	

DATA ELEMENTS	PREVIOUSLY COLLECTED FOR SOME SITES	COMMENT	PROPOSED PRIMARY DOCUMENT	DOCUMENTS LIKELY TO CONTAIN PROPOSED DATA ELEMENT INFO
AMD included in baseline risk assessment?				ROD Summaries Chronology of Major Tailings Dam Failures COC Source Summaries RI/FS database, or CERCLIS EPA Regional Office
Cause of release (inherent to operations, illegal activity, operator error, equipment failure, etc.)		May be difficult to determine. This element will have an associated comment field.	ROD	ROD documents, Administrative docket, RI/FS, General research, ERNS
Release caused by single process/waste management activity, or by multiple activities at the site		May be difficult to determine. A yes/no element, accompanied by a comment field.	ROD	ROD Summaries Chronology of Major Tailings Dam Failures COC Source Summaries RI/FS database, or CERCLIS EPA Regional Office
Cause of release (mining or processing practice(s))	✓		ROD RI/FS	ROD Summaries Chronology of Major Tailings Dam Failures COC Source Summaries RI/FS database, or CERCLIS EPA Regional Office
Cause of release (waste management practice)	✓		ROD RI/FS	ROD Summaries Chronology of Major Tailings Dam Failures COC Source Summaries RI/FS database, or CERCLIS EPA Regional Office
Did neighboring or prior facilities contribute to release?		May be difficult to determine. A yes/no element, accompanied by a comment field.	ROD	ROD Summaries CERCLIS

Exhibit III.2. Proposed Data Elements to Be Collected - Currently Operating Facilities

<table>
<tr><th>DATA ELEMENTS</th><th>POTENTIAL DATA SOURCES</th></tr>
<tr><td colspan="2">Facility Information</td></tr>
<tr><td>Facility Name</td><td rowspan="13">EPA Data
EPA Envirofacts
FRS
Biennial Report (BR)
CERCLIS
TRI
Dun & Bradstreet
Moody's</td></tr>
<tr><td>Alternate (Previous) Facility Names</td></tr>
<tr><td>Commodity Group</td></tr>
<tr><td>Commodity</td></tr>
<tr><td>Facility Type (i.e., mine, processor, mine/processor)</td></tr>
<tr><td>City, County, State</td></tr>
<tr><td>NAICS</td></tr>
<tr><td>Current Owner</td></tr>
<tr><td>Previous Owner</td></tr>
<tr><td>Operation Start Date</td></tr>
<tr><td>Historical Overview of the Facility (if available)</td></tr>
<tr><td>Current Mining and Processing Practices</td></tr>
<tr><td>Management of Residuals and Wastes</td></tr>
<tr><td colspan="2">Other Facility Characteristics</td></tr>
<tr><td>Latitude/Longitude</td><td rowspan="9">Comprehensive Database
EPA Envirofacts
Kuipers' Database
General research
Note: size of nearby population and proximity to sensitive areas data will be incorporated if previously collected and determined, or easily available from source documents. Additional GIS analysis was not conducted.</td></tr>
<tr><td>Site Acreage</td></tr>
<tr><td>Size of Nearby Population</td></tr>
<tr><td>Proximity to Groundwater</td></tr>
<tr><td>Proximity to Surface Waters</td></tr>
<tr><td>Proximity to Sensitive Environments (e.g., FWS approved areas, FEMA special designated areas)</td></tr>
<tr><td>Proximity to Sensitive Aquatic Areas</td></tr>
<tr><td>Contaminant Leaching Potential (low, medium, high)</td></tr>
<tr><td>Other Geological Characteristics (if available)</td></tr>
<tr><td colspan="2">Evidence of Non-permitted Releases (since 1980)</td></tr>
<tr><td>Name of Hazardous Substance</td><td rowspan="5">ERNS
EPA RODs
EPA Envirofacts
Administrative Docket
Health impacts data will be collected if readily available in source documents (contextual info.)</td></tr>
<tr><td>Quantity Released</td></tr>
<tr><td>Source/Cause of Release</td></tr>
<tr><td>Medium Affected</td></tr>
<tr><td>Environmental/Health Impacts (if available)</td></tr>
<tr><td colspan="2">Major Enforcement Actions</td></tr>
<tr><td>Major Enforcement Actions</td><td rowspan="2">EPA Envirofacts
ECHO Database
Company Websites
News Searches
General Research
EPA will also review NRD data previously collected and determine whether they can be used for this effort.</td></tr>
<tr><td>Agency Responsible for Regulatory Oversight</td></tr>
</table>

Appendix III.A.: Sample of Non-Operating Sites

NO.	SITE NAME	EPA ID	COMMODITY CATEGORIES	OPERATION TYPE
1	Shieldalloy Corp.	NJD002365930	Aluminum & Ferrous Metals & Non-Ferrous Metals	Other
2	Cimarron Mining Corp.	NMD980749378	Ferrous Metals & Non-Ferrous Metals	Other
3	Bueno Mill & Mine Site	CON000802129	Industrial Rocks & Non-Ferrous Metals	Mine
4	Bunker Hill Mining & Metallurgical Complex	IDD048340921	Industrial Rocks & Non-Ferrous Metals	Mine
5	Eagle Zinc Co Div T L Diamond	ILD980606941	Industrial Rocks & Non-Ferrous Metals	Other
6	Captain Jack Mill	COD981551427	Non-Ferrous Metals	Mine
7	Summitville Mine	COD983778432	Non-Ferrous Metals	Mine
8	Gilt Edge Mine	SDD987673985	Non-Ferrous Metals	Mine
9	Upper Tenmile Creek Mining Area	MTSFN7578012	Non-Ferrous Metals	Mine
10	Cyprus Tohono Mine	AZD094524097	Non-Ferrous Metals	Mine
11	Blackbird Mine	IDD980725832	Non-Ferrous Metals	Mine
12	Silver Mountain Mine	WAD980722789	Non-Ferrous Metals	Mine
13	National Zinc Corp.	OKD000829440	Non-Ferrous Metals	Other
14	Tex-Tin Corp.	TXD062113329	Non-Ferrous Metals	Other
15	Omaha Lead	NESFN0703481	Non-Ferrous Metals	Other
16	ASARCO, Inc. (Globe Plant)	COD007063530	Non-Ferrous Metals	Other
17	East Helena Site	MTD006230346	Non-Ferrous Metals	Other
18	Li Tungsten Corp.	NYD986882660	Non-Ferrous Metals	Other
19	Chemet Co.	TND987768546	Non-Ferrous Metals	Other
20	Fields Brook	OHD980614572	Non-Ferrous Metals	Other
21	Coronet Industries	FLD001704741	Phosphates	Mine
22	Eastern Michaud Flats Contamination	IDD984666610	Phosphates	Other

NO.	SITE NAME	EPA ID	COMMODITY CATEGORIES	OPERATION TYPE
23	Monsanto Chemical Co. (Soda Springs Plant)	IDD081830994	Phosphates	Other
24	Stauffer Chemical Co. (Tarpon Springs)	FLD010596013	Phosphates	Other
25	Midnite Mine	WAD980978753	Radioactive Metals	Mine
26	Westlake Landfill OU2	MOD079900932	Radioactive Metals	Mine
27	Homestake Mining Co.	NMD007860935	Radioactive Metals	Other
28	United Nuclear Corp.	NMD030443303	Radioactive Metals	Other
29	Teledyne Wah Chang	ORD050955848	Rare Earth Minerals	Other

Appendix III.B.: Sample of Currently Operating Facilities

NO.	FACILITY NAME	STATE	COMMODITY GROUP	COMMODITY	FACILITY TYPE
1	Noranda Gramercy	LA	Aluminum	Alumina	Processing/Refining
2	Sherwin Alumina	TX	Aluminum	Alumina	Processing/Refining
3	Century Hawesville	KY	Aluminum	Aluminum	Processing/Refining
4	Noranda New Madrid	MO	Aluminum	Aluminum	Processing/Refining
5	Alcoa Mount Holly	SC	Aluminum	Aluminum	Processing/Refining
6	McGeorge Alabama Mine	AR	Aluminum	Bauxite	Surface Mine
7	Saint Gobain Bauxite Calciner	AR	Aluminum	Bauxite	Processing/Refining
8	Saint Gobain Bauxite Mine	AR	Aluminum	Bauxite	Surface Mine
9	Saint Gobain Fort Smith Calciner	AR	Aluminum	Bauxite	Processing/Refining
10	Resco Hillsborough	NC	Aluminum	Bauxite	Surface Mine
11	ArcelorMittal Minorca	MN	Ferrous Metals	Iron Ore	Surface Mine
12	Northshore Mining Silver Bay	MN	Ferrous Metals	Iron Ore	Processing/Refining
13	United Taconite Thunderbird Mine	MN	Ferrous Metals	Iron Ore	Surface Mine
14	US Steel Minntac2	MN	Ferrous Metals	Iron Ore	Processing/Refining
15	Penn Mag	PA	Ferrous Metals	Iron Ore	Processing/Refining
16	CML Iron Mountain2	UT	Ferrous Metals	Iron Ore	Surface Mine
17	New Riverside Ochre	GA	Industrial Rock	Barite Barium Ore	Surface Mine
18	Halliburton Rossi	NV	Industrial Rock	Barite Barium Ore	Surface Mine
19	Nutritional Additives Sexton	NV	Industrial Rock	Barite Barium Ore	Surface Mine
20	Rio Tinto Borax	CA	Industrial Rock	Boron	Surface Mine
21	Searles Valley Minerals Trona1	CA	Industrial Rock	Boron	Brine Extraction
22	Searles Valley Minerals Trona2	CA	Industrial Rock	Boron	Processing/Refining
23	Searles Valley Minerals Westend	CA	Industrial Rock	Boron	Processing/Refining
24	Industrial Minerals Plant2	SC	Industrial Rock	Boron	Processing/Refining
25	Premier Chemicals Gabbs	NV	Industrial Rock	Brucite	Surface Mine
26	Hastie Mining Klondike II	KY	Industrial Rock	Fluorspar	Surface Mine
27	Intrepid Potash East	NM	Industrial Rock	Potash	Underground Mine
28	Great Salt Lake Minerals Ogden	UT	Industrial Rock	Potash	Solar Evaporation
29	Intrepid Moab	UT	Industrial Rock	Potash	Solution Mine
30	Intrepid Potash North	NM	Industrial Rock	Potash	Processing/Refining
31	US Antimony Montana	MT	Non-Ferrous Metals	Antimony	Processing/Refining
32	First Liberty Lovelock	NV	Non-Ferrous Metals	Antimony	Processing/Refining
33	First Liberty Fencemaker	NV	Non-Ferrous Metals	Antimony	Underground Mine
34	KMI Zeolite Shenandoah	NV	Non-Ferrous Metals	Brucite	Processing/Refining

NO.	FACILITY NAME	STATE	COMMODITY GROUP	COMMODITY	FACILITY TYPE
35	Nyrstar Clarksville Cadmium	TN	Non-Ferrous Metals	Cadmium	Processing/Refining
36	PennMag Plant2	PA	Non-Ferrous Metals	Chromite Chromium Ore	Surface Mine
37	Stillwater Columbus	MT	Non-Ferrous Metals	Cobalt	Processing/Refining
38	ASARCO Ray Hayden	AZ	Non-Ferrous Metals	Copper	Processing/Refining
39	ASARCO Ray Hayden	AZ	Non-Ferrous Metals	Copper	Surface Mine
40	ASARCO Silver Bell1	AZ	Non-Ferrous Metals	Copper	Surface Mine
41	Cyprus Tohono	AZ	Non-Ferrous Metals	Copper	Surface Mine
42	Freeport McMoRan Tyrone1	NM	Non-Ferrous Metals	Copper	Surface Mine
43	Robinson Nevada	NV	Non-Ferrous Metals	Copper	Surface Mine
44	Rio Tinto Kennecott Magna1	UT	Non-Ferrous Metals	Copper	Processing/Refining
45	Rio Tinto Kennecott Copperton	UT	Non-Ferrous Metals	Copper	Processing/Refining
46	Indium Germanium	NY	Non-Ferrous Metals	Germanium	Processing/Refining
47	Umicore Germanium	OK	Non-Ferrous Metals	Germanium	Processing/Refining
48	Nyrstar Clarksville Germanium	TN	Non-Ferrous Metals	Germanium	Processing/Refining
49	Coeur Kensington	AK	Non-Ferrous Metals	Gold	Underground Mine
50	Apache Mining Old Wasp Mine	AZ	Non-Ferrous Metals	Gold	Surface Mine
51	Sixteen To One Mine	CA	Non-Ferrous Metals	Gold	Underground Mine
52	Barrick Cortez Underground	NV	Non-Ferrous Metals	Gold	Underground Mine
53	Barrick Goldstrike Mill	NV	Non-Ferrous Metals	Gold	Processing/Refining
54	Barrick Goldstrike Mine	NV	Non-Ferrous Metals	Gold	Surface Mine
55	Florida Canyon Mine	NV	Non-Ferrous Metals	Gold	Surface Mine
56	Geo Nevada Spring Valley	NV	Non-Ferrous Metals	Gold	Surface Mine
57	Newmont Chukar	NV	Non-Ferrous Metals	Gold	Underground Mine
58	Newmont Mill 6	NV	Non-Ferrous Metals	Gold	Processing/Refining
59	Veris Gold Jerritt Canyon	NV	Non-Ferrous Metals	Gold	Processing/Refining
60	Waterton Global Hollister Mine	NV	Non-Ferrous Metals	Gold	Underground Mine

NO.	FACILITY NAME	STATE	COMMODITY GROUP	COMMODITY	FACILITY TYPE
61	Kinross Crown Resources Buckhorn Mine	WA	Non-Ferrous Metals	Gold	Underground Mine
62	Indium New York	NY	Non-Ferrous Metals	Indium	Processing/Refining
63	Umicore Rhode Island	RI	Non-Ferrous Metals	Indium	Processing/Refining
64	Doe Run Buick	MO	Non-Ferrous Metals	Lead-Zinc Ore	Underground Mine
65	Doe Run Fletcher	MO	Non-Ferrous Metals	Lead-Zinc Ore	Underground Mine
66	Doe Run Sweetwater	MO	Non-Ferrous Metals	Lead-Zinc Ore	Underground Mine
67	FMC Bessemer Lithium	NC	Non-Ferrous Metals	Lithium	Processing/Refining
68	Rockwood Lithium	NV	Non-Ferrous Metals	Lithium	Brine Extraction
69	US Magnesium	UT	Non-Ferrous Metals	Magnesium	Brine Extraction
70	Freeport McMoRan Morenci2	AZ	Non-Ferrous Metals	Molybdenum	Processing/Refining
71	Freeport McMoRan ClimaxMoly1	CO	Non-Ferrous Metals	Molybdenum	Underground Mine
72	Freeport McMoRan ClimaxMoly2	CO	Non-Ferrous Metals	Molybdenum	Processing/Refining
73	Freeport McMoRan HendersonMoly2	CO	Non-Ferrous Metals	Molybdenum	Processing/Refining
74	Thompson Creek	ID	Non-Ferrous Metals	Molybdenum	Surface Mine
75	Ashdown	NV	Non-Ferrous Metals	Molybdenum	Underground Mine
76	Stillwater East Boulder	MT	Non-Ferrous Metals	Platinum Group Ore	Underground Mine
77	Stillwater Stillwater	MT	Non-Ferrous Metals	Platinum Group Ore	Underground Mine
78	ASARCO Amarillo-Selenium	TX	Non-Ferrous Metals	Selenium and tellurium	Processing/Refining
79	Hecla Greens Creek Silver	AK	Non-Ferrous Metals	Silver Ore	Underground Mine
80	US Silver Galena	ID	Non-Ferrous Metals	Silver Ore	Underground Mine
81	Coeur Rochester	NV	Non-Ferrous Metals	Silver Ore	Surface Mine
82	DuPont Florida	FL	Non-Ferrous Metals	Titanium	Surface Mine
83	Iluka Resources Concord	VA	Non-Ferrous Metals	Titanium	Surface Mine
84	Iluka Resources Stony Creek	VA	Non-Ferrous Metals	Titanium	Processing/Refining
85	Nyrstar Clarksville	TN	Non-Ferrous Metals	Zinc	Processing/Refining
86	Nyrstar East Tennessee Complex- Coy	TN	Non-Ferrous Metals	Zinc	Underground Mine

NO.	FACILITY NAME	STATE	COMMODITY GROUP	COMMODITY	FACILITY TYPE
87	Nyrstar East Tennessee Complex-Young	TN	Non-Ferrous Metals	Zinc	Underground Mine
88	Nyrstar Middle Tennessee Complex-Elmwood/Gordonsville	TN	Non-Ferrous Metals	Zinc	Underground Mine
89	Monsanto/P4 South Rasmussen-Blackfoot Bridge1	ID	Phosphates	Phosphate Rock	Surface Mine
90	Monsanto/P4 South Rasmussen-Blackfoot Bridge2	ID	Phosphates	Phosphate Rock	Processing/Refining
91	Simplot Don	ID	Phosphates	Phosphate Rock	Processing/Refining
92	Mosaic Uncle Sam	LA	Phosphates	Phosphate Rock	Processing/Refining
93	Simplot Vernal	UT	Phosphates	Phosphate Rock	Surface Mine
94	Mosaic South Pasture Hardee	FL	Phosphates	Phosphate Rock	Surface Mine
95	Energy Fuels Pinenut Mine	AZ	Radioactive Metals	Uranium	Underground Mine
96	Energy Fuels White Mesa Mill	UT	Radioactive Metals	Uranium	Processing/Refining
97	Lost Creek	WY	Radioactive Metals	Uranium	ISL
98	Uranium One Willow Creek	WY	Radioactive Metals	Uranium	ISL
99	Materion Elmore	OH	Rare Earth Minerals	Beryllium	Processing/Refining
100	Materion Delta	UT	Rare Earth Minerals	Beryllium	Processing/Refining
101	Materion Natural Resources Utah	UT	Rare Earth Minerals	Beryllium	Surface Mine
102	Molycorp Mountain Pass1	CA	Rare Earth Minerals	Rare Earths Ore	Surface Mine
103	Molycorp Mountain Pass2	CA	Rare Earth Minerals	Rare Earths Ore	Processing/Refining
104	Columbus Project	NV	Rare Earth Minerals	Rare Earths Ore	Surface Mine
105	Southern Ionics Mission North Mine	GA	Rare Earth Minerals	Zirconium and hafnium	Surface Mine
106	Southern Ionics Mission South Mine	GA	Rare Earth Minerals	Zirconium and hafnium	Surface Mine
107	ATI Wah Chang	OR	Rare Earth Minerals	Zirconium and hafnium	Processing/Refining
108	Western Zirconium	UT	Rare Earth Minerals	Zirconium and hafnium	Processing/Refining
109	AK Steel Middletown	OH	Ferrous Metals	Iron Ore	Blast Furnace
110	ArcelorMittal Indiana Harbor	IN	Ferrous Metals	Iron Ore	Blast Furnace
111	US Steel Great Lakes Ecorse	MI	Ferrous Metals	Iron Ore	Blast Furnace

Appendix IV: Summary of Federal and State Regulations Potentially Applicable to Hardrock Mining and Mineral Processing Facilities

Introduction

Under this task, EPA researched and identified currently applicable federal and state regulations designed to prevent and minimize releases of hazardous substances at hardrock mining and mineral processing facilities. Using both the direct text of laws and regulations and secondary sources, we reviewed environmental regulations to determine their applicability to hardrock mining and mineral processing operations and the extent to which these programs were delegated to states for implementation. Where public information was available, we also noted any pending changes or additions to the regulatory landscape. We reviewed state policies to identify unique regulatory programs at the non-federal level. Given the large number of states, we selected eight states associated with 71 percent of facilities within the currently regulated universe for this round of review.

Tables A through N detail our findings, describing applicable federal and state-level regulations. The following text summarizes the methods and major findings.

Methods

We conducted a literature review of both federal and state-level laws and regulations designed to prevent hazardous releases from hardrock mining and mineral processing facilities. We considered regulations governing preliminary environmental assessment, discharges to water, land reclamation, and solid waste disposal. We also briefly reviewed air regulations and summarize them below, but not in the tables that follow. A future, more detailed review of air regulations can examine the regulatory framework for hazardous air releases.

First, we reviewed federal regulations that potentially apply to hardrock mining and mineral processing. Secondary sources such as academic articles, legal analyses, non-profit and government agency-produced reports, and industry guides provided sources of information on potentially applicable regulations. To confirm information gathered from secondary sources and to supplement our research with the most recently promulgated rules, we reviewed the text of rules promulgated under major environmental laws, as well as the relevant federal agency guidance and notices of ongoing rulemakings. These included: the Federal Land Policy and Management Act, CWA, RCRA, Safe Water Drinking Act, UMTRCA and CAA.

Next, we reviewed state-level regulation for the eight states with the most hardrock mining and mineral processing facilities: Alaska, Arizona, California, Idaho, Minnesota, Montana, Nevada, and Utah. Each of these states includes over 15 facilities within the currently operating universe; together, they include 71 percent of facilities. Upon EPA's direction and in an effort to consider potential regulations for commodities not represented in these eight states, we supplemented our review by including five additional states: Arkansas, Florida, Indiana, Tennessee, and Texas. Overall, the states we reviewed include over 76 percent of sites within the currently operating universe. Few recent secondary sources discuss regulation at the state level. Thus, for each state, most of our findings are based on direct review of regulations and any applicable state agency guidance. We also considered whether each state managed a delegated federal environmental program, such as water quality permitting.

Findings

On the federal level, landmark environmental laws such as the CWA, SDWA, and CAA form the basis for environmental requirements for HRM/P activities. While some states, such as California, had environmental statutes preceding these federal laws, the passage of major federal environmental laws in the 1970s established a uniform framework for environmental protection in all states. The Environmental Protection Agency (EPA) delegates implementation of CWA, SDWA and CAA programs to most states, with these rules making up a large part of the state-level regulatory framework for hardrock mining.

While the Resource Conversation and Recovery Act (RCRA) generally excludes mining wastes and many processing wastes from its “cradle-to-grave” management framework through the 1980 Bevill Amendment, federal and state agencies have adopted rules regulating hardrock mining and mineral processing under CWA, CAA, and SDWA. Federal toxic substance regulations in the 1990s and 2000s often identified mineral extraction and processing industries as one of the target regulated industries (for example, the CAA National Emissions Standards for Hazardous Air Pollutants (NESHAPs) and CWAELGs).

For issues surrounding solid waste, groundwater quality, and permitting and reclamation on non-federal lands, multiple states have promulgated their own regulatory frameworks for mining operations, which vary widely across the states reviewed. Over time, state mining reclamation laws shifted from focusing on coal mining operations only, to cover metals and ultimately surface mining. All of the initial eight states reviewed (those with the largest numbers of facilities) have enacted surface mining management and reclamation laws. Minnesota was the first to enact a surface mine reclamation requirement for minerals (in 1969), while Arizona was the last (in 1996). Hardrock mining has a much smaller presence in the five additional states reviewed, and we found regulations in these states to be less comprehensive and to focus on specific minerals and commodities rather than broad hardrock mining issues. Of these five states, Arkansas, Tennessee, and Florida regulate surface mining across hardrock commodities. Regulations in Texas focus on coal and uranium operations, while Indiana regulates coal and stone quarry operations at the state level.

Environmental Assessment and Reclamation

Permitting for operations, preliminary environmental assessment, and reclamation requirements attempt to mitigate environmental damages through advanced planning. The BLM and, to a lesser extent, the USFS permit and oversee mining activities on public federal lands. These agencies are charged with preventing "unnecessary and undue degradation" to public lands, and generally require the submission and approval of plans of operation for proposed activities, including an environmental assessment and reclamation plans. BLM has required reclamation of lands since 1987, and USFS has required reclamation since 1974.

Much of the hardrock mining in the initial eight states reviewed occurs on either federal or state public lands. While BLM and USFS oversee mining activities on federal land, state-level mining regulations in these eight states apply to mining operations on both private and public lands. Many states also maintain memoranda of understanding with the federal government to share responsibility for management of mining on public lands. The level of detail in environmental assessment and reclamation requirements varies in the text of rules and regulations and agency guidance across federal and state regulations. For example, BLM guidance states that particular mining claims may require appropriate mitigation and reclamation measures in plans of operations given anticipated potential environmental impacts, but that generally BLM land use plans do not prohibit certain mining practices through zoning. While some states mirror BLM's management guidance, Montana Code Part 3 (Metal Mine Reclamation) details specific reclamation actions at sites that must be conducted and prohibits certain mining practices. In the past decade, several Congressional bills have been introduced to expand the scope and specificity for environmental performance on federal land, although no legislation has been ratified.[655]

In the five additional states reviewed, state generally did not establish comprehensive regulatory programs for hardrock mining, possibly because of the relatively smaller mineral extraction sectors in these states. For example, Texas has promulgated reclamation standards only for uranium operations. In Indiana, local authorities, rather than state agencies, establish requirements for land use and reclamation.

Water Pollution

Potential releases to water supply constitute a source of concern with respect to hardrock mining and mineral processing operations. The federal CWA authorizes federal regulations to prevent the degradation of water and wetlands in the United States. Generally, NPDES permitting and federal water quality standards, or their EPA-approved state equivalents regulate point-source discharges to water sources from industrial operations. Federal regulation that specifically manages HRM/P operations can be found in the industry-based ELGs under the CWA. The ELGs for ferro-alloy manufacturing, metal mining and processing, and ore mining and dressing point sources lay out maximum effluent limitations based on technology-based standards, and sometimes require NPDES permits for these operations to incorporate certain best management practices.

These rules do not cover all potential sources of water pollution. Mining pits protected by cover do not qualify as point sources from a "discrete conveyance," and do not fall under point-source

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[655] Hardrock Mining and Reclamation Acts of 2009 (H.R. 699, S. 796), 2014 (H.R. 5060), amending the General Mining Law of 1872.

requirements under the CWA.[656] Further, some regulatory uncertainty exists regarding how mining overburden, slurry, and tailings are regulated under the CWA, because of different definitions of fill material used by EPA and the USACE. EPA issues and oversees point-source discharge permitting under Section 402 of the CWA, while USACE issues "fill and dredge" permits under Section 404 of the CWA. Thus, Section 404 permits have been issued for mining operations outside of Section 402 NPDES permitting requirements.[657]

Regulations under the federal SDWA and delegated state programs also manage Class III and Class V underground injection wells through permitting and technical standards. Class II wells are used to extract minerals such as copper and uranium through in situ solution mining methods, and Class V wells can be used for solution mining and often serve as on-site disposal systems for mine backfill. Uranium in situ mining and processing is also permitted and managed specifically through NRC regulations.

Waste Disposal

The federal RCRA and delegated state programs exempt mining-related extraction, beneficiation, and 20 mineral processing wastes from Subtitle C hazardous waste requirements. Non-exempt processing wastes, such as emissions control dust and pickle liquor from iron and steel production and spent potliners from aluminum processing, are subject to RCRA's permitting and monitoring requirements. RCRA Land Disposal Restrictions also establish treatment standards for metal and mineral processing wastes exhibiting toxicity characteristics, regulating the disposal of these wastes in underground injection control wells. Nevertheless, most mining waste regulation can be found at the state level. Arizona's Department of Environmental Quality, for example, requires APPs specifically for mine tailing piles and ponds, surface impoundments, and solid waste disposal facilities at mine sites. Nevada water pollution control regulations and California mining waste management regulations each have minimum design criteria and performance standards for the specific management of mining waste.

Releases to Air

While the following tables do not include federal or state regulations designed to prevent hazardous air releases, we briefly summarize them here. Under Section 112 of the CAA, EPA has promulgated NESHAPs for several sources specific to processing operations. These may specify technology-based performance standards, emissions limits, and operational requirements intended to reduce certain air pollutants from processors of certain materials. Several of the states reviewed, including Alaska, Arizona, and Utah, have partially or fully incorporated these standards for delegated implementation. Some states also implement independent air toxics programs, many of which preceded federal NESHAPs. Idaho's Toxic Air Pollutants (TAP)

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[656] *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010).

[657] C. Copeland, "Controversies over Redefining 'Fill Material' Under the Clean Water Act," *Congressional Research Service* RL31411 (Washington, DC: U.S. Government Printing Office, 2013).

program regulates a larger set of air pollutants than federal NESHAPs, establishing limits of each contaminant for ambient air concentrations or stack-based emissions levels. Nevada's Mercury Control Program, established in 2006, requires mercury emissions controls on thermal units located at gold and silver mines.

Summary Tables

Following this discussion, Tables A through I detail our findings, describing federal and state-level regulations potentially applicable to hardrock mining and mineral processing facilities.

Table A. Federal Laws and Regulations Applicable to Releases from Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
BLM "3809" regulations – federal surface mining regulations	43 CFR Part 3809	N/A	General	For disturbances of more than five acres on BLM lands, operators must submit a plan of operations, which includes performance standards, mitigation measures, and waste management and reclamation plans. BLM must assess the operation's likely environmental impacts before approving the plan, and can require the operation to conform to BLM's land use plans. BLM land use plans, however, must recognize Mining Law rights, and cannot zone areas to prohibit certain types of mining operations or practices. For operations less than 5 acres, operators must notify BLM and complete reclamations required under previous notices before commencing; BLM approval is not required. BLM can share or defer responsibility for lands management with states through Memoranda of Understanding or Joint Management Agreements.	Preliminary environmental assessment	
Forest Service land management regulations	36 CFR Part 228; Forest Service Manual 2800-2007-2	N/A	General	Forest Service manages mining and its impacts under the standard of the 1897 Organic Act, which grants the Secretary of Agriculture power to promulgate rules to regulate "occupancy and use and to preserve the forests thereon from destruction." It also administers the National Forest Management Act. The "228" regulations require plans of operations for all mechanized mining or exploration operations regardless of acreage if there is significant disturbance of surface resources; the plans may involve a detailed environmental analysis and reclamation plan. Forest Service also requires posting of financial assurance; and establishes performance standards.	Preliminary environmental assessment	
National Environmental Policy Act	P.L. 91-190; 42 USC §4321 et seq	No	General	Requires environmental review process (such as an environmental assessment, or a more extensive environmental impact statement) for actions	Preliminary environmental assessment	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
(NEPA)				requiring federal approval. Could be triggered by: • Application for permits for activities on Forest Service land • Approval process for Plans of Operations (which include reclamation plans) for hardrock mining and/or milling operations on federally managed lands (BLM) • Approval of mineral leases and sales on federal or tribal lands or federal mineral estates • Federal permitting processes such as NPDES wastewater discharge permits issued by EPA or Section 404 (dredge and fill) permits issued by USACE or CAA 176(c) permits for non-attainment areas.		
Hardrock Mining and Reclamation Acts of 2009, 2014	HR 699, S. 796 (2009); HR 5060 (2014) [not ratified]	N/A	General	Would amend the General Mining Act of 1872 to expand and make more specific the requirements for environmental performance on federal land. The provisions include: • Increasing acreage of land closed to exploration and development, with input permitted from local governments • Giving land managers the ability to balance mineral activities with other public uses • Establishing mining-specific standards for reclamation, surface and groundwater protection, and ongoing water quality. Regulations would be promulgated to address topsoil replacement, surface stability, sediment prevention, leachate control, vegetative cover, and impoundment design and operation. After operations cease, water quality standards would need to be attained for five years without treatment. • Establishing a reclamation fund from mining royalties Requiring increased inspections, authorizing citizen suits, and proscribing operators currently in violation or with numerous past violations from receiving new permits	Preliminary environmental assessment; Operational Requirements;	Passed the House of Representatives in November 2007, but was not taken up by the Senate, and was re-introduced in the 111th and 113th Congresses. Has not been ratified.

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Media-Specific Regulation						
CAA Section 112 – National Emission Standards for Hazardous Air Pollutants (NESHAPs)	40 CFR Part 63	Partial	Air	• **Ferroalloys production** major sources (64 FR 27450, 5/20/99); area sources (73 FR 78637, 12/23/2008; proposed rule revision 79 FR 60238,10/6/2014) • **Iron and steel foundries** major sources (69 FR 21905, 4/22/04); area sources (73 FR 226, 1/2/2008); • **Primary aluminum reduction plants** (70 FR 66285, 11/2/05; proposed supplemental rulemaking 79 FR 72914, 12/8/14) • PVC and copolymers production, **primary copper smelting**, secondary copper smelting, and **primary nonferrous metals: zinc, cadmium, and beryllium** (72 FR 2930, 1/23/2007) • Aluminum, copper, and other nonferrous foundries area sources (74 FR 30366, 6/25/2009) • Gold mine ore processing and production area sources (76 FR 9449, 2/17/2011) • **Primary lead smelting** major sources (76 FR 70834, 11/15/2011) • **Primary magnesium refining** major sources (68 FR 58615, 10/10/03) • **Taconite iron ore processing** major sources (68 FR 61867, 10/30/03)	Varies by rule. Requirements include:	
CWA Section 401 - state certification	CWA Section 401 (PL-95-217)	Yes	Water	Any applicant for federal licenses or permits (including mining on federal land) may be required to obtain certification from the state that the applicant's discharges into navigable waters will comply with state water quality standards.	Certification	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
CWA Section 402 - NPDES permits for point-source discharges	CWA Section 402 (PL-95-217)	Partial	Water	NPDES permits (or state equivalents) required for all point-source discharges, requiring monthly discharge monitoring reports (DMRs).	Permit; Operational requirements; Performance standards	Mining pits protected by cover do not qualify as point sources, and do not fall under this requirement.[658]
CWA Section 402(p) – NPDES stormwater permit	CWA Section 402 (PL-95-217)	Partial	Water	NPDES stormwater permit (or state equivalent) required for stormwater collected into a "discrete conveyance," including construction ditches and stormwater contaminated by contact with material from mining activities. Includes industrial stormwater discharges, including from metal mining.	Permit; Performance standards	
CWA Section 402(p) – NPDES stormwater permit	CWA Section 402 (PL-95-217)	Partial	Water	Discharges from abandoned mines should be subject to NPDES permits where the owners or operators of point sources who are legally responsible for the discharges can be identified. State NPDES programs are responsible for implementing the NPDES permit program with respect to discharges from abandoned mines for which a responsible owner or operator has been identified.	Permit; Performance standards; Operational requirements	
CWA Section 303(c) – Water Quality Standards	40 CFR Part 131	Partial	Water	States and tribes are directed to establish Water Quality Standards (WQS) to support designated uses and prevent degradation. These standards, which must be approved by EPA, support other water regulatory programs, including NPDES permitting. The National Toxics Rule establishes numeric criteria for priority toxic pollutants, by chemical, for 14 states that do not otherwise have similar regulations under Section 303(c)(2)(B) of the CWA.	Performance standards	
CWA Title III - ELGs	40 CFR 424 (ferro-alloy manufacturi ng); 40 CFR 436 (mineral mining and	No	Water	Mine drainage or process water (but not stormwater) is subject to ELGs.	Technology-based standards; Performance standards; Operational requirements	

[658] *Greater Yellowstone Coalition v. Lewis*, 628 F.3d 1143 (9th Cir. Dec 23, 2010).

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
	processing); 40 CFR 440 (ore mining and dressing)					
CWA Section 404 – Dredge-and-Fill permits	33 CFR Part 323	Partial	Water	Permits are required from the USACE for dredge-and-fill activities that discharge into U.S. waters, including mining tailings piles.	Permit	While CWA Section 402 and 404 do not overlap as written, some regulatory uncertainty regarding mining overburden, slurry, and tailings exists because of different definitions of fill material used by EPA and USACE. As such, Section 404 permits have been issued for mining operations that do not have Section 402 NPDES permits.[659]
Rivers and Harbors Act Section 10 - Construction permit	33 CFR Part 322	No	Water	Permits are required from the USACE for construction activities in or over navigable U.S. waters.	Permit	
RCRA Subtitle C Hazardous Waste – Bevill exemption for mining wastes	40 CFR 261.4(b)(7)	Partial	Waste	In general, hazardous waste generators must provide notification, but are not required to obtain permits; hazardous waste management facilities are subject to permitting. Mining-related extraction and beneficiation wastes and 20 special mineral processing wastes, however, are excluded from RCRA Subtitle C by the Bevill Amendment (40 CFR 261.4(b)(7)).[660]	N/A	EPA reported in 1997 that Subtitle C applied on a limited basis to 400 mineral processing sites that may generate characteristic hazardous waste. Only a few mineral processing sites had Subtitle C permits; most

[659] For more information, see C. Copeland, "Controversies over Redefining 'Fill Material' Under the Clean Water Act," *Congressional Research Service* RL31411 (Washington, DC: U.S. Government Printing Office, 2013).

[660] Several Subtitle C provisions are potentially applicable to mining but have not been historically applied (no regulations promulgated). These include:

- Section 2002(a): Authorities of Administrator to prescribe regulations as necessary to fulfill RCRA functions
- Section 3001(b)(3)(B)(iii): Administrator may prescribe regulations to prevent radiation exposure which creates human health risks from the extraction, beneficiation, and processing of phosphate rock or overburden from the mining of uranium ore

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				Although mineral processing wastes are generally excluded from regulation under RCRA Subtitle C, spent potliners from primary aluminum reduction (K088), emission control dust/sludge from the primary production of steel in electric arc furnaces (K061), and spent pickle liquor generated by steel finishing operations at facilities within the iron and steel industry (K062) are regulated as hazardous waste under RCRA.		shipped wastes off-site to avoid Subtitle C requirements.[661]
RCRA Subtitle C Land Disposal Restrictions (LDR)	40 CFR Part 268; 63 FR 28556, 5/26/1998	Partial	Waste	LDR ensure that hazardous waste cannot be placed on land until the waste meets specific treatment standards to reduce the mobility or toxicity of the hazardous constituents. This "Phase IV Rule" finalized treatment standards for several metal wastes and certain newly-identified mineral processing wastes, and revised the universal treatment standards for twelve metal constituents. It applies Universal Treatment Standards (UTS) to newly identified characteristic mineral processing waste. These standards control disposal of certain mineral processing wastes in underground injection control wells. Hazardous waste regulations were modified to define which secondary materials from mineral processing are considered waste, and are thus subject to LDR treatment standards. The rule	Operational requirements	

- Section 3001(b)(3)(C): promulgation of new regulations for Bevill wastes or determination that such regulations are unwarranted
- Section 3004(x): the Administrator is authorized to modify regulations for solid waste from the extraction, beneficiation or processing of ores and minerals, including phosphate rock and overburden from the mining of uranium by taking into account the special characteristics of such wastes

[661] U.S. Environmental Protection Agency, *EPA's National Hardrock Mining Framework* (Washington, DC: U.S. Government Printing Office, 1997), p. C-28. Accessed December 31, 2014, at https://nepis.epa.gov/Exe/ZyNET.exe/91019GVM.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1995+Thru+1999&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C95thru99%5CTxt%5C00000032%5C91019GVM.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				eliminates current regulatory distinctions between mineral processing sludges, by-products and spent materials and creates a new class of materials referred to as mineral processing secondary materials eligible for a conditional exclusion from the definition of solid waste. Materials that are legitimately recycled and kept off the land prior to recycling are conditionally excluded. It applies only to primary mineral processing; it makes no changes to the regulatory status of extraction/beneficiation wastes. EPA did not reopen the Bevill determinations. The rule did not alter the regulatory status of listed wastes or wastes from secondary mineral processing facilities.		
SDWA regulations	40 CFR Parts 143-148	Partial	Water	Oversees underground injection wells, which may endanger groundwater supplies. Part 146 describes technical standards for various classes of injection wells. Mining sites must apply for permits for UIC Class 3 wells (wells associated with mineral recovery).	Permit; Operational requirements	
Toxic Substances Control Act – PCB regulations	40 CFR Part 761	No	General	Banned production of equipment containing PCBs. The mining industry has traditionally used high levels of PCBs in transformers and capacitors.	Operational requirements	
NRC uranium mining and processing regulations	10 CFR Part 20; 10 CFR Part 40; Appendix A to 10 CFR Part 40	No	General	Regulates uranium processing and in situ solution mining on public and private lands. Does not regulate traditional (mechanical) uranium ore mining separately from other federal and state agencies. Permitting and regulation of in situ uranium mines. Part 20 establishes standards for protection against radiation, including monitoring and waste disposal. Part 40 establishes domestic licensing of source material. Appendix A to Part 40 promulgates criteria relating to the operation of	Permit; Operational requirements	Pending rulemaking: NRC In Situ Leach Uranium Recovery Facility (ISL) Working Group to revise Appendix A in 10 CFR Part 40 to clarify the regulations related to groundwater protection, and to update the requirements in Appendix A to be consistent with EPA drinking water MCLs.

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				uranium mills and the disposal of tailings or wastes produced from uranium ores.		Another goal is to reduce dual regulation.[662]
UMTRCA	PL 95-604	No	General	Mandates special closure designs for uranium mill tailings ponds to prevent radon gas releases. Under Title I of UMTRCA, the U.S. DOE is responsible for site cleanup and remediation at abandoned uranium and thorium milling sites. NRC is responsible for evaluating the design and implementation of these projects, and for ensuring concurrence with EPA standards.	Operational requirements	
BLM "3809" regulations – federal surface mining regulations	43 CFR Part 3809	Partial	General	Mining operations on BLM land must prevent unnecessary or undue degradation, including by following accepted notices or approved plans of operation, and by following reasonable and customary mineral exploration sequences. Other requirements include proper disposal, concurrent reclamation, and providing for post-mining monitoring, maintenance, and treatment. BLM has required reclamation since 1987. BLM conducts quarterly inspections of operations using cyanide, biannual inspection of other producing operations, and biannual inspection of nonproducing activities that result in disturbance requiring reclamation.	Performance standards; Operational requirements	In November 2000, new 3809 rules defined more specific standards for mine operation, reclamation, and closure and improved federal financial assurance, which previously had been undefined in the 1980 promulgation. They also made it easier for BLM to deny permits for ecological reasons. In 2001, BLM retained a revised form of bonding provisions of the 3809 regulations, but returned the substance of most others to their 1980 form.[663]
Forest Service "228" regulations – federal surface mining regulations	36 CFR Part 228; Forest Service Manual 2800-2007-2	Partial	General	Mining operations on Forest Service land must minimize adverse environmental impacts, including by following approved plans of operation and complying with applicable federal and state laws. Forest Service has required reclamation since 1987, which must be conducted	Performance standards	

[662] "In-Situ Leach Rulemaking," U.S. Nuclear Regulatory Commission. Accessed January 6, 2014, at http://www.nrc.gov/materials/uranium-recovery/regs-guides-comm/isl-rulemaking.html#ri.

[663] A.P. Morriss, R.E. Meiners, and A. Dorchak, "Between a Hard Rock and a Hard Place: Politics, Midnight Regulations, and Mining," *Administrative Law Revie*w 55:3 (2003), p. 551-606. Accessed December 31, 2014, at: http://www.jstor.org/discover/10.2307/40712239?sid=21105530626993&uid=3739696&uid=2&uid=3739256&uid=4.

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED TO STATES	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				at the earliest practicable time or within one year of conclusion of operations.		

Table B. Alaska: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Mining Reclamation Statute	ALASKA STAT. §§ 27.19 Reclamation; 11 AAC 97.310	No	General	Before starting operations on state, federal, or private lands, the commissioner of natural resources must approve a reclamation plan (27.19.030). Mining facilities in violation of an approved reclamation plan are liable for the full amount of reclamation and administrative costs, and may be subject to suspended or revoked permits for other operations (27.19.070).	Permit; Preliminary environmental assessment	
General Prospecting Permit and Lease Provisions; Alaska Department of Natural Resources (ADNR approval of Plan of operations	11 AAC 86.800	No	General	For operations on state lands, a plan of operations must show how the facility operator will comply with performance standards, stipulations, or conditions applicable to the prospecting permit or lease. The proposed plan of operations must address the areas to be mined, location and design of settling ponds, tailings disposal, overburden storage, permanent or temporary diversions of water, access routes, reclamation plans, and other actions necessary to conduct the operation. Among a list of other tasks the plan must be approved by the Department of Fish and Game, Department of Environmental Conservation, and other applicable agencies.	Preliminary environmental assessment	
Application for Permits to Mine in Alaska (APMA)	ADNR	No	General	APMA is a form for permits required for a range of mining operations, including placer mining. Placer mines may need a Fish Habitat Permit from the Department of Fish and Game. Generally, though, placer mine waste that has not been amalgamated or chemically treated is regulated under the same regulation as other mining waste.	Permit	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Media-Specific Regulation						
Alaska Pollution Discharge Elimination System (APDES) Permits	18 AAC 15; 18 AAC 83; 18 AAC 72	Yes (2010–present))	Water	Required for any mining operation that is going to discharge wastewater to state waters (point sources). Permits include effluent limits for various pollutants in the wastewater, which comply with Alaska water quality standards. Permits also set monitoring and reporting requirements.	Permit; Performance standards	
Alaska Water Quality Standards	18 AAC 70	Yes	Water	This regulation sets the state standards for water quality, including color, contaminant levels, radioactivity, sediment, and other pollutants (industrial, municipal, agricultural).	Performance standards	
Alaska Pollutant Discharge Elimination System (APDES) Construction General Permit (ACGP)	18 AAC 83	Yes	Water	This permit authorizes stormwater discharges from construction activities that result in a total land disturbance of one acre or less, limits the amounts and types of substances that can be discharged into waters of the state of Alaska, and sets monitoring and reporting mandates to ensure that any discharge leaving a construction project site. The Storm Water Pollution Prevention Plan (SWPPP) describes the design, installation, and maintenance of effective erosion controls, sediment controls, and pollution prevents measures appropriate for each site.	Permit; Performance standards	
Alaska Department of Environmental Conservation (ADEC) Solid Waste Disposal Permit	Title 18 AAC Chapter 60 – Solid Waste Management	No	Waste	This permit and underlying statute are designed to ensure that landfills, treatment facilities, and solid waste storage facilities are designed, built, and operated to minimize health and safety threats, pollution, and nuisances, and to prevent violations of the state air quality and water quality standards. Excluded from regulation are waste rock from mining operations and tailings from placer mining that have not been amalgamated or chemically treated. Other mine tailings are regulated under 18 AAC 60.455, except when the only chemical being used is a	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				flocculent to enhance settling. Tailings from hardrock mines and tailings from placer mines that have been amalgamated or chemically treated are subject to the State solid waste management general standards, requirements, limitations, waste disposal permits, monofill regulations, user fees, and monitoring and corrective action requirements. These permits usually require pre-operational, operational, and post-closure monitoring.		
Alaska land reclamation performance standards	AS 27.19.020; 11 AAC 97.200-240	No	General	Mining operations must be reclaimed to prevent unnecessary degradation of land and water. Reclamation must be conducted as contemporaneously as practicable with the mining operation to leave the site in stable condition. Reclaimed areas should not have a stream flowing over it after reclamation. These standards allow for the reestablishment of renewable resources on the site within “a reasonable period of time by natural processes.” The standards require that buildings, structures, and debris on state land be removed. Additionally, these standards require operators to seal all openings of underground mines for protection of public, wildlife, and environment. Heap leach operations require neutralization and approval by the appropriate regulatory authority (EPA/DEC). These standards require the site to be reclaimed to standards of AS 27.19. The standards require that mined areas be reclaimed if there is potential to generate AMD to prevent discharge/generation of AMD.	Operational requirements	

Table C. Arizona: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Mineral Leases Authorization for Locatable Minerals	ARS §27-231 through 27-256	No	General	For state lands, a Mineral Development Report must be submitted with the mineral lease application, including an environmental assessment, biological evaluation, and mine operation, reclamation, and closure plans. The lessee must receive authorization in the form of approved Mine Operation and Reclamation and Closure Plans.	Preliminary environmental assessment	
Mined Land Reclamation Plan; Aggregate Mined Land Reclamation Plan	ARS §27-901 et seq. and 27-1201 et seq.; AAC R11-2-101 through R11-2-822	No	General	The Reclamation Plan or the Aggregate Mined Land Reclamation must be submitted and approved for all metal mining units and exploration operations with surface disturbances on private lands greater than five acres. Plan provides measures for: revegetation, financial assurance, topsoil requirements, erosion control, and waste removal. The Office of the Arizona State Mine Inspector administers the Arizona Mined Land Reclamation Act (AMLRA) (passed in 1994), and the implementing regulations (promulgated in 1997). Metal processing facilities are exempt, as are surface disturbances on state lands.	Permit; Preliminary environmental assessment	
Media-Specific Regulation						
APP	ARS §§49-241 through 49-252; AAC R18-9-101 through R18-9-403	No	Water	Arizona DEQ regulates discharges from mining operations under the Aquifer Protection Program. A variety of facility types listed under Arizona law as categorical discharging facilities must obtain an	Permit; Technology-based standards; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				APP. Specific to mining, these facilities include: mine tailing piles and ponds, surface impoundments, solid waste disposal facilities at mine sites, mine leaching operations, wetlands associated with mine water treatment; and injection wells (such as those found in in situ copper leach operations). The applicant must show that the best demonstrated control technology will be used by the facility, and that Aquifer Water Quality Standards (AWQS) will not be exceeded. Dry wells must be registered with ADEQ, to minimize groundwater impacts and ensure that only stormwater enters a dry well. Closure of dry wells must follow ADEQ's Dry Well Decommissioning Guidelines. Exempt sites include mining overburden returned to the excavation site including any common material which has been excavated and removed from the excavation site and has not been subjected to any chemical or leaching agent or process of any kind.		
Arizona Department of Water Resources (ADWR) Withdrawal and Use of Groundwater Permit	ARS §45	No	Water	When mines are included in the five active management areas for groundwater, management plans include conservation requirements to: regulate transport tailings density, reduce water loss from tailings impoundments, minimize water use in leaching processes, and prepare a long-range conservation plan.	Operational standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Arizona Pollutant Discharge Elimination System (AZPDES) permits	ARS §255.01; 18 AAC 9, Article 9	Yes	Water	The State of Arizona enforces its own version of NPDES: the AZPDES. ADEQ issues individual permits tailored for specific facilities based on individual applications, and general permits for multiple facilities within a specific category, industry, or area. Permits include effluent limitations, based on technology and water quality standards, and monitoring or reporting requirements to evaluate wastewater treatment efficiency. As part of the Industrial Stormwater Program, ADEQ requires all mining facilities on non-tribal lands to obtain the AZPDES Multi-sector General Permit (referred to as an "AZPDES MSGP 2010 permit" for mining). Must submit a SWPPP. A permit is required unless discharges from conveyances used for collecting precipitation runoff from mining operations are composed entirely of non-contact stormwater uncontaminated by mining operations. Mining facilities are generally required to obtain a point-source discharge permit for mine drainage.	Permit; Performance standards, technology-based standards	
Arizona Water Quality Standards For Surface Waters	AAC 18-11	Yes	Water	The Arizona Water Quality Standards for surface waters describe designated uses, anti-degradation requirements, narrative water quality standards, numeric water quality standards/targets, discharge prohibitions, and drinking water standards. It also provides standard levels by substance type and discharge prohibitions.	Performance standards; Technology-based standards	

Table D. Arkansas: State-level Laws and Regulations Applicable to Releases from Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Open-cut and In-stream Mine Permits – general and individual	Arkansas Act 827 of 1991; Arkansas Pollution Control and Ecology Commission Regulation No. 15.301 – 15.313	No	General	Permits are required for all open-cut and in-stream mining. Permit application includes maps of the region with descriptions of water flow patterns, mining plans with descriptions of release mitigation and topsoil preservation measures, and reclamation plans. Permit terms shall not exceed five years. For in-stream mines, the mining plan must include storm and process water containment, map of permit area, and a stream cross section. Groups of mines can apply for a general permit if they are similar in nature and if they, separately or together, would only have minimal impacts on the environment.	Preliminary environmental assessment; Permit	
Quarry permit	Arkansas Act 1166 of 1997	No	General	Applies to all new quarries or land purchased for quarry after 1997. Facilities must submit a notification of intent to quarry, including area boundaries, a map of operations and topographic characteristics, and a notice of intent to reclaim the area afterwards. After notification, facilities are allowed to quarry indefinitely unless the Arkansas Department of Environmental Quality (DEQ) issues a temporary cessation due to environmental or health reasons.	Permit; Operational requirements; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Media-Specific Regulation						
Open-cut mine standards	Arkansas Act 827 of 1991; Arkansas Pollution Control and Ecology Commission Regulation No. 15.401 and 15.402	No	General	Open-cut mines are subject to requirements surrounding slope of piles, dam construction, reclamation, maintenance of vegetative cover, and buffer zones between the mine and adjacent waterways. Mines must submit an annual report to Arkansas DEQ. Lakes left as part of reclamation must remain within a pH of 6 and 9 unless otherwise allowed. Arkansas DEQ must approve the disposal method for mine spoil.	Operational requirements; Performance standards	
In-stream mining standards	Arkansas Act 827 of 1991; Arkansas Pollution Control and Ecology Commission Regulation No. 15.401 and 15.403	No	General	In-stream mines must ensure that material removal remains below the high water mark, that they do not violate any of the state's water laws, and that removal does not alter stream course or create channel instability. In-stream mines are required to reclaim areas to prevent erosion and ensure bank stability. Mining in streams designated as "extraordinary resource waters" is not allowed.	Operational requirements; Performance standards	
Quarry standards	Arkansas Act 1166 of 1997	No	General	After completion of quarrying activities, companies are required to reclaim the land to at least a lake, pasture, timberland, wetland, or combination thereof. Alternatively, a comparable amount of other post-reclaimed land can be left. Topsoil and spoil should be stockpiled and returned to site. Stormwater and process water are regulated under the operator's stormwater pollution prevention plan and NPDES permit, respectively.	Permit; Operational requirements; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Arkansas NPDES individual permits	Arkansas Pollution Control and Ecology Commission Regulation No. 6.202	Yes	Water	ADEQ has the responsibility to issue NPDES permits. All persons who construct, operate, or modify any disposal system that discharges industrial wastes or other wastes into state waters shall apply for a state permit. Facilities are subject to standards set out by the "Recommended Standards for Sewage Works," published by the Great Lakes-Upper Mississippi Board of State Sanitary Engineers. All discharges of wastewater in the Lake Maumelle Basin are prohibited, except for NPDES stormwater discharges.	Permit; Operational requirements; Performance standards	
NPDES stormwater permit for industrial facilities (ARR000000)	Arkansas Water Pollution Control Act; Arkansas Pollution Control and Ecology Commission Regulation No. 6	Yes	Water	Stormwater discharges from industrial sites are granted an NPDES general permit, currently in effect until 2019, provided that sites meet certain criteria. The permit is available for discharges from primary metals, metal mining, and mineral mining and dressing sectors. Requirements include the following: • Each facility must prepare a SWPPP, which includes a description of the facility, description of potential sources of pollution, mitigation measures, and other requirements. • Required management practices include minimizing exposure of potential pollutant sources to rain, snowmelt, and runoff, regularly maintaining equipment, implementing certain spill prevention and response measures,	Operational requirements; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				implementing erosion and sediment controls, and managing runoff. • Facilities are required to monitor stormwater once per year for a wide range of contaminants, including a wide range of metals. The concentrations of these contaminants should be compared against certain "benchmark" concentrations to assess the effectiveness of BMPs, although exceeding these does not count as a permit violation.		
NPDES stormwater permit for construction facilities (ARR00A000)	Arkansas Water Pollution Control Act; Arkansas Pollution Control and Ecology Commission Regulation No. 6.203	Yes	Water	Stormwater discharges from construction sites are granted an NPDES general permit, currently in effect until 2016, provided that sites meet certain criteria and provide a Stormwater Pollution Prevention Plan. BMPs include erosion controls, soil stabilization, pollution prevention, and dewatering. Sites must not cause a violation of state or federal water quality standards.	Operational requirements	
Arkansas water quality standards	Arkansas Pollution Control and Ecology Commission Regulation No. 2	Partial	Water	The Arkansas Pollution Control and Ecology Commission adopts standards for the state to protect designated uses of water. Includes standards for minerals, bacteria, clarity, temperature, oil and grease, acidity or alkalinity, dissolved oxygen, nutrients, and toxic substances, and other factors.	Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Arkansas Pollution Control and Ecology Commission Regulation No. 23; Arkansas Hazardous Waste Management Act	Ark. Code, Ann Sects. 8-7-202 et seq; Arkansas Pollution Control and Ecology Commission Regulation No. 23	Yes	Waste	Arkansas DEQ implements RCRA Subtitle C, as well as its own Arkansas Hazardous Waste Management Act. The Arkansas law includes several standards that Arkansas identifies as more stringent than the federal law. • Mining and mineral processing waste is only considered hazardous if it is mixed with other solid wastes defined by Arkansas as hazardous and if contaminant concentrations in the mixture exceed certain maximum levels, and would not have been exceeded solely by mining waste alone. • An impermeable coating is required for drip pads (264.571(b)) and all surfaces of the secondary containment structure for container storage areas.(264.175(b)(2))	Permit; Operational requirements	
Arkansas Hazardous Waste Regulations	40 CFR Part 26; Arkansas Pollution Control and Ecology Commission Regulation No. 23	Yes	Waste	Arkansas is currently authorized to implement the RCRA Subtitle C base program. Although mineral processing wastes are generally excluded from regulation under RCRA Subtitle C, spent potliners from primary aluminum reduction (K088), emission control dust/sludge from the primary production of steel in electric arc furnaces (K061), and spent pickle liquor generated by steel finishing operations at facilities within the iron and steel industry (K062) are regulated as hazardous waste under RCRA and delegated state programs.	Permit; Performance standards; Operational requirements	

Table E. California: State-Level Regulations applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Surface Mining and Reclamation Act (SMARA) reclamation plan and assessment	14 CCR § 2.8.1	No	General	Individual county and city governments issue and enforce all mining permits in California. Applies to surface mining operations on state, federal, private, or Indian land disturbing more than 1 acre or removing more than 1,000 cubic yards of materials. The Act passed in 1975. Requires a reclamation plan, which includes California Environmental Quality Act (CEQA) slope stability, vegetation, and groundwater studies, an erosion control plan, compliance with a range of environmental laws, topographic maps, mining and reclamation phasing maps, a biological survey, and settling pond and spillway designs.	Permit; Preliminary environmental assessment	
CEQA	14 CCR 6.3 § 15000-15387	No	General	Applies to discretionary projects made by California state agencies, including the issuance of permits. Requires a Preliminary Review to determine significance and an Environmental Impact Report if the action is found to be significant. Includes review guidelines particular to surface mining. Agencies cannot approve projects if feasible alternatives exist that substantially lessen their significant environmental impacts.	Preliminary environmental assessment	
MOU between the California Surface Mining and Geology	"Surface mining and reclamation	No	General	Establishes how these agencies will work cooperatively in order to meet all of the requirements of	Preliminary environmental assessment	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Board (SMGB), U.S. Department of the Interior (DOI), and the USFS	coordination in the State of California," 1992			federal, state, and local laws, particularly California's Surface Mining and Reclamation Act.		
Media-Specific Regulation						
SMARA reclamation standards	14 CCR Div. 2.8.1 §3700	No	General	Mining operations must practice environmental impact mitigation and reclamation as specified in their operating permits. These codified standards represent minimum reclamation that must be conducted. Permitting agencies can incorporate more stringent requirements on a site-specific basis. Minimum reclamation standards incorporate land stability, recontouring, revegetation, soil quality, and water quality maintenance.	Performance standards; Operational requirements	
Porter-Cologne Water Quality Control Act; State Water Resources Control Board Mining Waste Management Regulations	27 CCR Div. 7.1	No	Waste; Water	All mining units (including surface impoundments, waste piles, and tailings ponds) subject to Waste Discharge Requirements (WDRs) must comply with the siting and construction standards. Mining wastes are classified into three groups (A, B, and C) based on their potential hazard to water, including their acid-generating potential. Disposal and management regulations are based, to an extent, on these hazard groups. The law establishes monitoring, siting and construction, and closure standards for mining units. Operators must have a closure and post closure maintenance plan. Waste units	Technology-based standards; Performance standards; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				must still comply with performance standards based on their hazard group.		
Porter-Cologne Water Quality Control Act; Regional water quality boards permitting and water quality standards	27 CCR Div. 4	Yes	Water	Water quality standards are established at the sub-state level by nine regional water quality boards, based on local needs and hydrological conditions. These local boards issue permits and take enforcement actions. Regional water boards may issue discharge standards specifically for mine waste.	Permit; Performance standards	
Regional Water Quality Control Boards - NPDES program (Waste Discharge Requirements)	27 CCR Div, 4.4	Yes	Water	California's nine Regional Water Quality Control Boards issue NPDES permits, also referred to as Waste Discharge Requirements, to regulate the discharge of municipal wastewater or industrial process, cleaning, or cooling wastewaters, commercial wastewater, treated groundwater from cleanup projects, or other wastes to surface waters only. If the waste discharge consists only of non-process stormwater, it may be regulated under the NPDES Stormwater program. The discharge of waste to the ground surface or to groundwater is regulated under the Non-Chapter 15 Permitting, Surveillance, and Enforcement Program.	Permit; Performance standards; Technology-based standards	
California Hazardous Waste Regulations	22 CCR Div. 4.5 §66261	No	Waste	Mining overburden and mining wastes are excluded from classification under RCRA, but may be regulated as hazardous wastes in California if they exhibit characteristics listed in Chapter 11, Article 3, §66261.	Permit; Operating requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				California’s hazardous waste management system establishes permitting procedures and operating requirements for generators and transporters of hazardous waste, as well as hazardous waste management facilities.		

Table F. Florida: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Florida Department of Environmental Protection (FDEP) Mandatory Nonphosphate Program	62-343 FAC; 62-671 FAC; 62C-16 FAC; 378.101 FS, 378.102 FS	No	Water	This program, administered by FDEP, regulates heavy minerals, fuller's earth, limestone, dolomite and shell gravel and other solid resources. It consists of two permitting programs and a post-mining reclamation program. These programs cover heavy minerals, but exclude phosphate. The wetland resource permit (WRP) program requires wetland resource permits for the Northwest Florida Water Management District for operations in state wetlands and surface waters, or wetlands and surface waters with multiple owners. Operations regulated under this program include dredging, filling, and construction. In other parts of the state, environmental resource permits (ERPs) are required for the creation or alteration of water bodies including old mine pits. ERPs consider an operation's impact on wetlands, water quality and quantity, and wildlife. The ERP combines the authority of water management districts under the management and storage of surface waters (MSSW) program with the regulatory authority of FDEP under the wetland resource permit program.	Permit; Performance standards	There are 67 counties and approximately 390 municipalities that may regulate activities at mines at the local level. The aspects regulated and the degree of the regulation differ for each local government. Local regulation may include: conformance with the Comprehensive Land Use Plan, impacts to wetlands, operating permits, reclamation, setbacks from property lines, stormwater management, truck routes, noise, performance bonding, garbage disposal, etc.
Developments of Regional Impact (DRI) Process	380.06 FS	No	General	The DRI process is a comprehensive review of state law, conservation of plant and wildlife resources, and impacts to: archaeological and historical resources, hazardous material usage, potable water, wastewater, and solid waste, transportation, air quality, and housing, including affordable housing. This program provides state and	Preliminary environmental assessment	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				regional review of large developments, including any solid mineral mining operation which is expected to disturb more than 100 acres per year, or which consumes more than three million gallons of water per day. Additionally, mines that will be reclaimed to large residential, commercial, or industrial areas are considered DRI.		
Media-Specific Regulation						
Florida Water Quality Standards	62-302 FAC	Yes	Water	FDEP reviews, establishes, and revises the state water quality standards. The Florida Water Quality standards describe classifications of water bodies, general and cite specific criteria, an anti-degradation policy, and special protection of Outstanding Florida Waters (OFW). FDEP is currently developing biological and numeric nutrient criteria.	Performance standards	
FDEP Wetland Resource (WR) Permit	62-312 FAC	No	Water	In certain Water Management Districts, operations in, on, or over, wetlands or surface waters require WR permits. Florida Administrative Code 62-312 establishes a method to consider hydric soils, wetland plants, and hydrologic indicators to identify the limits of wetlands and surface water. The WR permit regulates dredging, filling, and construction. In water districts other than the Northwest Florida Water Management District, the Wetland Resource Permit sets stormwater standards.	Permit; Operational requirements	
FDEP ERP	62-343 FAC	No		Covers operations in, on, or over wetlands and surface water in Water Management Districts not regulated by WR permits. It does not apply to mines in the Northwest Florida Water Management District. All mines except for borrow pits without on-site sorting	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				or grading apply for an ERP through the FDEP. Some mines may still be grandfathered from the ERP, and may use the MSSW and/or Wetland Resource permits. In most cases, these are mines with existing permits or formal wetland delineation determinations.		
FDEP Stormwater Discharge Program	62-25 FAC	Partial	Water	This FDEP program implements NPDES stormwater standards for facilities that discharge pollutants associated with fugitive dust or contain outdoor storage of raw materials and byproducts. If a facility is not also required to have a NPDES wastewater permit, then EPA Region 4 administers the permit. This program regulates operations in the Northwest Florida Water Management District only. In other Water Management districts, stormwater standards are included in Wetland Resource Permits.	Permit; Operational requirements	
FDEP Industrial Wastewater (IW) Permit Program	62-4 FAC	Yes	Water	These permits regulate point-source water and industrial discharges, and can incorporate federal NPDES wastewater and stormwater permit standards, including ELGs. Industrial categories covered include phosphate mining and beneficiation, ore mining and dressing, and phosphate manufacturing. General IW Permits are registered to operations that can contain process wastewater and runoff from up to a 25-year, 24-hour storm event. Individual IW permits are required for operations that exceed this level. Industrial wastewater permits are issued by the district offices, with two exceptions. NPDES permits for steam electric power plants are issued by the Industrial	Permit; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				Wastewater Section. Some mining operations may be exempt from these permits. Industrial wastewater permitting for the phosphate industry is handled by the state Phosphogypsum Management Section.		
FDEP, USACE Dam Safety Program	373 FS; 62-672 FAC	No	Water	The dam safety program is regulated through statute Chapter 373 Water Resources, the Phosphate Management Rule 62-672, which contains operational requirements (such as water level and vegetation requirements) for active and retired dams, and the best management practices for non-clay, phosphate mining and reclamation berms and impoundments. FDEP inspects dams for phosphate mining and other industrial operations. In addition to FDEP and USACE, the Dam Safety program is administered by regional water management districts.	Operational requirements	
FDEP Mandatory Phosphate Program (MANPHO)	378.101 FS, 378.102 FS, 373.403-373.468 FS; 62C-16 FAC, 62-312 FAC, 62-4 FAC, 62-343 FAC, 62-341 FAC, and 40X-4 FAC,	No	General	This program administers the rules related to the reclamation of lands mined for phosphate after 1975. It also administers the rules related to Environmental and Wetland Resource Permits for phosphate mined lands. Reclamation requirements include water quantity impact analysis and best available technology consideration. Reclamation standards include safely contoured slopes, acceptable water quality and quantity, revegetation, waste management, and return of wetlands to premining state. Concurrent reclamation is not explicitly required, but the regulations establish completion dates for various reclamation activities ranging from six months to two years.	Performance standards; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Phosphogypsum Management	62-673	No	Water	This rule regulates phosphogypsum stack systems. It establishes procedures and permitting requirements and sets operational and closure standards for these systems.	Permit; Operational requirements	
Phosphate Mining Waste Treatment Requirements	62-671	Yes	Water	The phosphate mining waste treatment requirements adopt federal effluent limitations and new source requirements for mining and processing of phosphate bearing minerals.	Operational requirements; Performance standards	

Table G. Idaho: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Idaho Surface Mining Act; Department of Lands Reclamation Plan Approval	Idaho Code 47-15	No	General	Surface mining on private, state, or federal land requires an approved reclamation plan. Depending on the project size, the plan can be for concurrent reclamation, or after operations close. Reclamation should replace topsoil and stabilize vegetation. Each approved reclamation plan must have a performance bond; exploration using motorized earth moving equipment requires a notice; water quality must be maintained and affected lands and disturbed watercourses must be reclaimed. State is allowed to administer penalties for violation of the Act. Act does not apply to placer, dredge, or underground mining.	Preliminary environmental assessment	
Idaho Rules for Ore Processing by Cyanidation	IDAPA 58.01.13	No	Water	These rules regulate the procedures and requirements for permitting of cyanidation facilities, in order to safely contain, control and treat water associated with the cyanidation process. The rules cover construction, operation, and closure. Permit applications require environmental and risk management reviews.	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Idaho Dam Safety Program	Idaho Code 42-17; IDAPA 37.06.06; IDAPA 37.03.05	No	General	The dam safety program regulates dams through dam safety statutes and rules, and mine tailings impoundment structures rules. Mine tailings impoundment structures are any artificial embankment that is or will be more than 30 feet in height measured from the lowest elevation of the downstream toe to the maximum crest elevation, constructed for the purpose of storing mine tailings slurry (I.C. 42-1711). The Safety of Dams Statute was amended in 1978 to include regulation of mine tailings structures. IDEQ oversees the construction, enlargement, alteration, repair, operation, maintenance, and removal of dams. Owners of dams that are taller than 20 feet must file an application with plans and specifications prepared by a consultant to conform to IDEQ's safety standards. Owners of mine tailings impoundment structures must provide a surety bond payable to the Idaho Department of water quality for reclamation of the facility.	Permit	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Media-Specific Regulation						
Department of Water Resources Dredge Mining permit	Idaho Code 47-1322 ; IDAPA 20.03.01	No	General	Any placer mining operation that disturbs more than one half of an acre of land (private, state, or federal) is required to have a permit from the Idaho Department of Lands (IDL). Every permit requires a performance bond. Permits require that operators maintain water quality, through implementation of best management practices (including the development of nonpoint sediment control practices), and disturbed lands and watercourses must be reclaimed. Reclamation requires backfilling, grading, topsoil replacement, and vegetation. Among other requirements, potential water quality impact documentation is required. A reclamation plan is part of the permit approval process. IDL is required by the Dredge and Placer Mining Act to inspect operations periodically to review compliance with permits.	Permit	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Water Quality Standards	IDAPA 58.01.02	Yes	Water	Idaho DEQ is responsible for adopting and enforcing water quality standards that protect beneficial uses for the Idaho Water Quality Standards. EPA develops recommended criteria, regulations, policies, and guidance to help Idaho implement the Water Quality Standards Program and to ensure that Idaho's adopted standards are consistent with the requirements of the CWA and relevant regulations. Additionally, EPA has authority to review state standards and to promulgate federal water quality rules, if it finds the state is not meeting the requirements of the CWA. NPDES permits in Idaho for discharges, however, are administered by the EPA at the federal level.	Performance standards	
Department of Lands reclamation requirements	Idaho Code 47-15	No	General	Establishes specific reclamation requirements for every operator who conducts exploration or surface mining operations that disturb two or more acres within the state. Requirements include sediment control, clearing and grubbing limits, salvage of topsoil and overburden for later reclamation, road construction and rehabilitation, backfilling and grading at closure, waste disposal and protection from erosion and chemical impact, settling pond criteria, tailing impoundment criteria and rehabilitation, revegetation of disturbed areas. The Department of Lands conducts	Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				Inspections to review compliance with approved reclamation plan.		
Idaho Rules for Ore Processing	IDAPA 58.91.13	No	Water	This rule requires that, before disposal or abandonment of leached ore, concentrations of WAD cyanide or free cyanide and other pollutants in process-contaminated water draining from the leached ore must be reduced to a level set by the permit writer based on disposal method, location, and potential for surface water and groundwater contamination or have a pH of between 6.5 and 9 (stabilized).	Operational requirements	
Idaho Small Suction Dredge Mining General Permit (NPDES general permit)		No	Water	EPA issued an NPDES general permit requirement in 2013 for small suction dredge operations in Idaho. Operators of small suction dredges must obtain NPDES permit coverage before operation. The general permit covers small suction dredges with an intake nozzle size of five inches in diameter or less and with equipment rated at 15 horsepower or less. The general permit places conditions on the discharge of rock and sand from each mining operation to protect water quality and aquatic resources. These conditions include best management practices and prohibited discharge areas.	Permit; Operational requirements	

Table H. Indiana: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Mining Permits	Indiana Code 14-35-1-1	No	General	The state has statutory authority to grant permits for extraction, removal, and disposition of minerals on or under land or non-navigable waters. The Indiana Department of Natural Resources (IDNR) does not comprehensively regulate non-coal mining operations, however. Generally, local entities regulate mining of dimension limestone, peat, marl, gypsum, sand, gravel, and crushed stone through local land use regulations.	N/A	
Media-Specific Regulation						
Water Quality Standards	Article 2. Water Quality Standards; 327 IAC 2	Yes	Water	This regulation sets surface and groundwater standards for a list of minimum water quality standard parameters. It also requires operations that produce cyanides and cyanogen compounds to not drain these substances directly or indirectly into any sewer system or watercourse. Water treatment control facilities are required to submit monthly reports, regarding flow measurements and wastewater characteristics to the Indiana Department of Environmental Management (IDEM).	Performance standards; Permit	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
NPDES Program	327 IAC 15	Yes	Water	IDEM administers the NPDES program for the state and issues permits. This program controls point-source discharges of pollutants into state waters in accordance with state water quality standards. Permits are required for point-source discharges, two of which apply to mining (industrial and wet weather). Industrial permits regulate wastewater generated from production, requiring identification of all pollutants present in the effluent, determination of EPA technology-based guidelines or industry best available technology, determination of water quality based effluent limits, and draft permit with effluent limits.	Permit	
Solid Waste Program	329 IAC 10, 11, 12	Yes	Waste	IDEM's office of Land Quality regulates solid land disposal and processing facilities. Foundry waste, including slag, sludge, and baghouse dust, is regulated as non-municipal solid waste rather than hazardous waste. Generators of foundry waste must evaluate their waste and determine whether to send their wastes to restricted waste sites or solid waste facilities.		

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Indiana Hazardous Waste Regulations	40 CFR Part 26; 329 IAC 3-8	Yes	Waste	Indiana is currently authorized to implement the RCRA Subtitle C base program. Although mineral processing wastes are generally excluded from regulation under RCRA Subtitle C, spent potliners from primary aluminum reduction (K088), emission control dust/sludge from the primary production of steel in electric arc furnaces (K061), and spent pickle liquor generated by steel finishing operations at facilities within the iron and steel industry (K062) are regulated as hazardous waste under RCRA and Indiana Hazardous Waste Regulations. Additionally, certain mining and oil exploration waste is under jurisdiction of IDNR.	Permit; Performance standards; Operational requirements	

Table I. Minnesota: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Minnesota Environmental Policy Act (MEPA)	MAR 4410.0200 - MAR 4410.6500	No	General	Establishes a review process for state agency actions with a "significant" impact on the environment. An environmental assessment worksheet (EAW) is mandatory for: • Mineral deposit evaluation of deposits other than natural iron ore or taconite • Expansion of a stockpile, tailings basin, or mine by 320 or more acres • 25 percent or more expansion of a plant • Any case where a governmental unit with approval authority deems a "potential for significant impacts" An Environmental Impact Statement (EIS) is mandatory for: • Mineral deposit evaluation of 1,000 tons or more of radioactive material • Construction of a new tailings basin for a metallic mineral mine • Construction of a new metallic mineral processing facility • Any project where a governmental unit with	Preliminary environmental assessment	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				approval authority deems a "potential for significant impacts"		
Mineland Reclamation Act – Non-Ferrous Metallic Minerals Permit	MAR 6132.1000 – 6132.1400	No	General	All mining operations of nonferrous metallic minerals are required to have a permit. The application requires a mine waste characterization study, an environmental background study, a mining and reclamation plan, financial assurance, and annual reporting of actual mining and reclamation occurring. Mining companies must also submit a request for release from permit, which describes the post-closure activities and shows that environmental goals have been met.	Permit; Performance standards	
Mineland Reclamation Act – Permit to Mine Metallic Minerals.	MAR 6130.4200 - 6130.6300	No	General	Permit required for all mining operations for metallic minerals. Permits are subject to separate standards for ferrous and non-ferrous minerals. Requires a range of environmental and technical reviews carried out by mining company and reviewed by the state.	Permit	
Media-Specific Regulation						
Mineland Reclamation Act – Taconite and Iron Ore Mining Standards	MAC 6130.1000 - 6130.4100	No	General	All operations where iron is the predominant metal extracted must meet general criteria for siting. Criteria include minimizing impacts due to wind erosion and air emissions, reducing major watershed modifications, and	Permit; Performance standards; Technology-based standards; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				minimizing runoff and seepage. Requirements are specified for stockpiles management, blasting, vegetation, and other aspects of mining. Mining is not allowed in a range of "exclusion areas," including near certain water bodies and national monuments.		
Mineland Reclamation Act – Non-Ferrous Metallic Minerals Mining Reclamation Standards	MAC 6132.1000 – 6132.1400	No	General	During mining, reclamation, and closure, all non-ferrous mining permit holders must comply with storage and disposal standards for reactive mine waste and overburden, construction, operation, and closure standards for storage piles, tailings basins, and heap and dump leaching facilities, revegetation standards, blasting standards, subsidence standards, dust control standards, and standards for the closure / post-closure maintenance process.	Performance standards; Technology-based standards	
MAR Chapter 7035: Solid Waste - Solid Waste Management Standards	MAC Chapter 7035	Yes	Land	Definition of solid waste includes waste materials from mining activities. Excludes certain hazardous waste rocks, special nuclear wastes, and waste regulated under section 402 of the federal water pollution control act. Solid waste land disposal facilities must design, construct, and operate facilities based on environmental protection	Operational requirements; Performance Standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				requirements. Facilities are subject to a range of reporting and post-closure care requirements.		
Water Quality Standards for Protection of Waters of the State	MAC 7050.0100 - 7050.0465	Yes	Water	Water quality standards are based on seven separate use classes. Standards may be more stringent than federal CWA standards. Discharges are also regulated differently based on the size of the point source.	Performance standards	
State waters discharge restrictions /State Disposal System (SDS)	MAC 7053.0135 to 7053.0405	Yes	Water	Applies to all discharges of sewage, industrial, and other wastes to all waters of the state, both surface and underground. In addition to federal standards, permit holders are subject to effluent standards related to nutrients, pH, biochemical oxygen demand, total suspended solids, oil, and toxic or corrosive pollutants.	Performance standards	
CWA - Section 401 Certification		Yes	Water	Minnesota issues CWA 401 permits to protect federal and Minnesota water quality standards. Required for any activities that could discharge a pollutant into U.S. waters.	Permit; Performance standards	
DES/SDS storm water permit	MAC 7090.0010 – 7090.3080	Yes	Water	Minnesota has separate programs for construction, industrial activities, and municipal stormwater. Industrial activity permit required for industrial activity (as defined by the law) or where the commissioner determines that an activity may cause a breach of water	Permit; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				quality standards. Requires a stormwater pollution prevention plan. Conditional exclusions for no exposure are allowed if snow, rain, snowmelt, and runoff are not exposed to industrial materials.		
NPDES/ SDS water quality permit for wastewater discharges	MAC 7001.1000 – 7001.1150	Yes	Water	The Minnesota Pollution Control Agency issues NPDES permits to all wastewater discharges to surface waters, and issues State Disposal System (SDS) permits for the construction and operation of all wastewater disposal systems.	Permit; Performance standards	

Table J. Montana: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Exploration License, General Operating Permit, Multiple Quarry Permit (Montana Hard Rock Mining Reclamation Act)	ARM 17.24.101 - ARM 17.24.189 ; MCA 82-4-335	No	General	A permit is required for the exploration or mining of all ore, rock, or substances except oil, gas, bentonite, clay, coal, sand, gravel, peat, soil materials and uranium. Exploration licenses require a plan of operations explaining the exploration techniques and a reclamation plan. Exploration projects are subject to restrictions on road placement, impacts to streams, erosion control, and reclamation standards. Before mining, facilities must submit a reclamation plan detailing the surrounding environmental conditions and land uses, and a plan of action for restoring the land after mining is complete. Montana DEQ is allowed to place additional requirements onto the plan. A less extensive review is required for miners that disturb less than 5 acres of surface and stay within other parameters. The rule requires that small miners agree in writing not to pollute any streams, with recommended best management practices for mitigating impacts rather than formal standards. DEQ can issue an order suspending the license or permit if it causes harm to health and safety of people, causes harm to the environment, or remains in violation of a corrective action order.	Permit, Technology-based standards; Operational requirements; Preliminary environmental assessment	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Milling Permits (Montana Hard Rock Mining Reclamation Act)	ARM 17.24.101 - ARM 17.24.189	No	General	Milling operations are subject to permitting. In the permit application, operations must submit an operating plan that contains a description of the surrounding environment, a plan for milling, expected best management practices, and a reclamation plan. Rules apply to mills under permit after June 1, 1990.	Permit; Preliminary environmental assessment	
Hard Rock Mining Impact Plan and EIS (Hard Rock Mining Impact Act; Montana Environmental Policy Act [MEPA])	MCA Section 90-6 Part 3 and Part 4; MCA Section 75-1-201	No	General	Large scale hard-rock mining projects must write an impact plan, including an environmental impact assessment, as a prerequisite to getting a Montana Department of Environmental Quality (MDEQ) mining permit. Involves writing an EIS for state agency actions (incl. issuing a permit) that are considered to have a “significant” impact on Montana’s environment and are not exempt from MEPA.	Preliminary environmental assessment; Permit	
Memorandum of Understanding with the Federal BLM	BLM-MOU-MT921-0509	No	General	MOU governing all hard-rock mining activities that are regulated by the BLM under the Federal Land Policy and Management Act. Establishes framework for coordination on permitting, and environmental analysis and documentation.	Preliminary environmental assessment	
Media-Specific Regulation						
Opencut Mining Program permits	MCA 82-4-401 et seq	No	Waste	Permits are required for opencut mining operations. Requires a site evaluation by Montana DEQ, a statement that the operator will protect on- and off-site surface water and groundwater from deterioration of water quality and quantity, and statements about safe storage of stockpiles and management of paved roads.	Permit; Operational requirements; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				Permit requires an annual progress report to DEQ.		
Metal Mine Reclamation Standards	MCA Section 82-4 Part 3	No	General	Standards include specific operational and reclamation requirements for mineral mining that must be incorporated in the reclamation plan, including a 2 year time limit on reclamation after completion or abandonment, treatment of objectionable effluents, vegetative cover, and structural stability. Surface mining for gold or silver using heap leaching or vat leaching with cyanide ore-processing reagents is generally prohibited.	Operational requirements	
Strip and Underground Mine Reclamation Act	ARM 17.24.301 through 1309	No	Waste	Applies to mining of coal and uranium. Law has extensive standards for waste burial/storage/disposal, sediment control, groundwater protection, surface water protection, revegetation, wildlife protection, future land use, financial assurance, distance from population, and other factors.	Operational requirements; Performance standards	
Montana Water Quality Act; Water Quality Standards	MCA Section 75-5-301; ARM 17.30.601-641 (Surface Water); ARM 17.30-1001-1045 (Groundwater)	Yes	Water	Montana surface water and groundwater are subject to water quality standards, based on beneficial uses. Law and division of use classes are more extensive for surface water than for groundwater.	Performance standards	
Montana Water Quality Act; Montana Pollutant Discharge Elimination System (MPDES) General Permit	MCA 75-5 Part 4	Yes	Water	All point sources of wastewater discharge are required to obtain and comply with MPDES permits. General permits are also required for construction activities that include clearing, grading, grubbing, excavation, or other	Permit; Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				earth disturbing activities that disturb one or more acres and discharge stormwater to state surface waters. Effluent limits are based on federal CWA effluent standards, as well as additional effluent standards from the Montana government to protect beneficial uses and water quality standards.		
Montana Water Quality Act; Montana Groundwater Pollution Control System (MGWPCS) Permit	Yes	No	Water	MGWPCS Permit required for the owner or operator of any existing sources to discharge pollutants in groundwater. Conditions of the permit must assure compliance with groundwater quality standards.	Permit; Performance standards	
Montana Natural Streambed and Land Preservation Act “310” Permit	Mont. Const. art. IX, Section 1; MCA 75-7-102	No	Waste	A permit is required for any activity that alters a stream bed. Several activities are prohibited. Application must contain information regarding the proposed alteration. Project must minimize adverse impacts to the stream.	Permit; Operational requirements	

Table K. Nevada: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Nevada Administrative Code – Water Control: Water Pollution Control Permits	NRS 445A.300-NRS 445A.730; NAC 445A.228 - NAC 445A.420	No	Waste; Water	All mining facilities in existence after 9/1/1989 with the potential to degrade state waters are subject to permitting. Permit application must include an analysis of surrounding environmental conditions and the proposed mining technologies used. (NAC 445A.387). The permit is valid for 5 years as long as the operator remains in compliance with the terms of the permit. The permit is subject to public review. Facilities that process less than 36,500 tons of ore per year and less than 120,000 tons of ore over the lifetime of a project are subject to reduced review requirements.	Permit; Preliminary environmental assessment	
Nevada Administrative Code –Reclamation of Land Subject to Mining Operations or Exploration Permits: Reclamation Permit	NRS 519A.010 - NRS 519A.290; NAC 519A.010 - NAC 519A.240	No	Waste	Exploration and mining projects in Nevada are required to apply for a permit. The permit application must include a plan for reclamation including schedule, methods, a description of the expected land disturbances, a description of mitigation practices, and a plan for and a review of the surrounding environment. Regulation applies to all operations active as of 10/1/1990.	Permit; Preliminary environmental assessment	.

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
MOU between the Nevada Department of Environmental Protection (NV DEP) and BLM for Mining-Related Environmental Impact Statements within the State of Nevada	MOU 1793-NV920-0804 4/30/2008	Yes	General	Mining operations on BLM land in Nevada disturbing more than five acres require a plan of operations. The MOU includes guidance on NEPA compliance, and other federal reviews such as the Endangered Species Act and the National Historic Preservation Act) for resolving disputes between the two agencies during the planning process.	Preliminary environmental assessment	
Media-Specific Regulation						
Nevada Water Control Standards for holders of Water Pollution Control Permits (specific to mining facilities)	NRS 445A.300-NRS 445A.730; NAC 445A.424 - NAC 445A.447	No	Water	All mining facilities in existence after 9/1/1989 with the potential to degrade groundwater are subject to procedural requirements to prevent releases, minimum design criteria for fluid and waste management, performance standards for stabilization of ore and tailings, and monitoring requirements. Facilities are required to meet performance standards for effluent releases and stabilization of waste; facilities must meet minimum design criteria for waste disposal units, and must monitor performance.	Technology-based standards; Performance standards; Operational requirements	
Nevada Mining Reclamation Standards for holders of Reclamation Permits	NRS 519A.010 - NRS 519A.290; NAC 519A.245 - NAC 519A.345	No	Waste	All land disturbed by mining must be restored to a level of productivity equal to what it was before mining activity or equal to adjacent land uses. Facilities are required to stockpile topsoil in the area and return it after mining, as well as conduct re-vegetation of the land. Nevada Department of Natural Resources (NV DNR) can also require other reclamation processes. Exemptions can be made for open pits and rock faces that are not feasible to reclaim.	Operational requirements; Technology-based standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
Nevada Administrative Code - Water Controls: Nevada Water Quality Standards	NAC 445A.11704 – NAC 445A.22755	Yes	Water	Standards include acceptable contaminant concentrations, pH ranges, and temperatures for state waters. Standards are specific to each geographical area and water use. Standards also include corrective action requirements for hazardous contaminants in ground and surface water.	Performance standards; Operational requirements	
CWA: NPDES permit	NRS 445A.300 -445A.730; NAC 445A.070 - 445A.348; NRS 445A.465; 40CFR 122.26	Yes	Water	Federal permit (administered by NV DEP) for discharges into surface waters of the state. Permits contain performance standards required to meet state and federal water quality standards, and may also include best management practices. Certain activities, as defined by 40 CFR § 122.26(b)(14) require stormwater discharge permits. Permit application requires a Notice of Intent (NOI) and a Stormwater Pollution Prevention Plan. General Permit NVR300000 applies specifically to stormwater discharges from metals mining activities to Waters of the U.S.	Permit; Performance standards	
CWA: Nevada 401 Certification Program	CWA USC 33 1341—Section 401(a)(1)	Yes	Water	The State of Nevada certifies that federal actions do not violate state water quality standards. These usually involve Federal Energy Regulatory Commission (FERC) licensing for electric plants and discharges of dredge and fill materials, including from gravel mining.	Certification; Performance standards	
Nevada Administrative Code - Water Controls: Nevada UIC Permit	NRS Chapter 445A; NAC 445A.865 – NAC 445.925; NAC 445A.810 –	Yes	Water	Disposal in any underground injection well requires a permit. Permits are required as of 7/22/1987. Permits are issued for a period of 5 years. Regulations lay out five classes of wells, including types specifically associated with mining. Wells are	Permit; Performance standards; Operational standards.	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
	NAC 445.862			subject to several standards for placement, mechanical integrity, abandonment, and injection pressure, depending on the class of the well. Underground injection wells are also subject to monitoring requirements, technical standards for construction, injection methods, leak detection, and plugging and abandonment.		
Nevada Administrative Code - Sanitation: Nevada Solid Waste Regulations	NRS 444.440 – NRS 444.645; NAC 444.570 - NAC 444.7499	Yes	Waste	Solid waste disposal facilities and facilities holding construction and demolition wastes are subject to permitting, siting, monitoring, financial assurance, and technical standards. Nevada revised statutes state that no provision in NRS 444.440 - 444.620 may prevent a mining operation from disposing of waste from its own operation on site.	Technology-based Standards; Performance standards; Operational requirements; Permit	
Nevada Revised Statutes: Hazardous Materials: regulation of mills and by-products	NRS 459.300– NRS 459.370	No	Waste	Licensing and financial assurance are required for the milling and disposal of waste from thorium and uranium recovery and refining operations. A license also requires a review of potential environmental effects of the operation.	Permit	

Table L. Tennessee: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Tennessee Department of Environment & Conservation (TDEC) Surface Mining Permit	TDEC Rule 0400-3 et seq.; TCA§ 59-8-201 et seq.	No	General	The TDEC Division of Water Resources, Mining Section issues permits to operations that engage in mining and mining-related surface disturbances. Clay, stone, phosphate rock, and metallic ore mining operations require permits. The permit application requires a reclamation plan. The Mining Section has the right to inspect permitted sites when necessary. The application for a Surface mining permit requires information on the mining operations, mineral to be mined, and acreage to be disturbed.	Permit	
Media-Specific Regulation						
TDEC Solid Waste Management Permit-by-Rule	Rule Chapter 0400-11-01-.02(2) - .02(5); T.C.A. 68-211-106	Yes	Waste	The TDEC Division of Solid and Hazardous Waste Management administers Permit-by-Rule authorizations. Permit-by-Rule authorizations are required for any solid waste processing operation that changes the chemical or physical characteristics of a solid waste. A Permit-by-Rule application requires a written explanation of how an operation will comply with the applicable criteria and information regarding storage capacity. TDEC may inspect a facility without an announcement and has the responsibility to regulate solid waste processing facilities to protect the health of the public and environment.	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
TDEC Division of Water Resources NPDES Permit	Rule 1200-4-1,3,4, 5 ;T.C.A. 69-3-101; TCA 69-3-108(b),(2),(3),(4),(6)	Yes	Water	Under the Tennessee Water Quality Control Act, TDEC Division of Water Resources issues NPDES permits to municipal, industrial, and other operations that discharge wastewater. Mining facilities are required to obtain NPDES discharge permits. Mining and other industrial operations must submit information regarding flow, source of pollution, and treatment, treatment technologies, and methods to reduce pollutants in discharge, as part of the application process. The permit program sets pollution control and monitoring requirements based on water quality standards and other applicable state and federal rules.	Permit	
Tennessee Water Quality Standards General Rules; General Water Quality Criteria	Rule 0400-40-02	Yes	Water	This rule establishes criteria for seven classified uses of water, and contains Tennessee's Antidegradation Policy. The rule identifies Exceptional Tennessee Waters, and establishes that these areas are unsuitable for mining, pursuant to the federal Surface Mining Control and Reclamation Act. The rule states that groundwater from "Acid Production Zone from Mining Activities" (e.g., areas in which acid mine/rock drainage occurs) is unusable.	Performance standards; Operational requirements	
Tennessee Storm Water Multi-Sector General Permit for Industrial Activities	TCA 69-3-101	Yes	Water	This permit regulates point source discharges of stormwater associated with industrial activities. In accordance with a storm water prevention plan and effluent standards (0400-40-04), a number of industry sectors are authorized to discharge stormwater runoff. Those sectors include: metal mining, construction sand and gravel mining and processing, dimension stone mining	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				and quarrying facilities, and primary metals facilities. The application for this permit includes a notice of intent for Storm Water Discharges Associated with Industrial Activity and an annual Storm Water Monitoring Report.		
TDEC Division of Water Resources Aquatic Resource Alteration Permit (ARAP)	Rule 0400-40-07	No	Water	The TDEC Division of Water Resources issues permits to facilities that wish to make alterations to a body of water or wetland. Examples of these types of alterations include dredging, channel widening, diversions, dams, and wetland draining.	Permit	
TDEC Certificate of Approval and Safety for Dams	Rule 0400-45-07; TCA § 69-11-101 et seq.	No	Water	The removal, alteration, construction, and operation of a non-federal dam each require approval from the TDEC Division of Water Resources, Dams Section. The application for this permit requires descriptions of the dam and reservoir as well as the designs for the dam. The division may inspect the site periodically and assess financial penalties for violations.	Permit	
TDEC - UIC Permit	Rule 0400-45-6; TCA 69-3-101 et seq.	Yes	Water	The TDEC Division of Water Resources, Ground Water Management Section regulates facilities that discharge industrial or chemical waste into subsurface systems other than city sewers. The Division also regulates facilities that modify certain topographical characteristics key to groundwater drainage (Karst features). The permit requires a UIC application. Additional application materials include chemical analysis of injection fluid, process descriptions, operation and maintenance procedures, and	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				erosion and sediment control descriptions. The Division may inspect a facility annually or as necessary. Class III wells can be used to inject fluids for mineral extraction and Class V wells include a variety of mineral recovery wells.		

Table M. Texas: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
TCEQ Radioactive Material License	30 TAC Subpart L; 30 TAC Chapters 336, 37, 39, 50, 55, 80, 281, 305; Texas Health and Safety Code 401	Yes	General	Texas is an "Agreement State" under the Atomic Energy Act. In situ uranium recovery operations are required to obtain a radioactive material license. In applying for this license, potential operators must include environmental and safety review elements in the NRC's NUREG-1569, "Standard Review Plan for In Situ Leach Uranium Extraction License Application." TCEQ will inspect these operations at least annually for operator permit compliance.	Permit	
Texas Railroad Commission (RRC) surface coal mining and reclamation requirements	Tex. Nat. Res. Code Ann. § 134.012 et seq	No	General	Texas surface coal mining and reclamation requirements require permits for coal, lignite, and uranium. Texas does not require statewide permits for mining other minerals. Iron ore and iron ore gravel mining may also be regulated under the Texas Surface Coal Mining and Reclamation Act and associated regulations depending on the scope of the mine. Permit requirements for both surface and underground mines include the submission of environmental data and a reclamation plan.	Permit	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
RRC Uranium Exploration Permit Program	Title 4, Mines and Mining, Chapter 131, Texas Uranium Exploration, Surface Mining and Reclamation Act	No	General	Permit is required for uranium mining exploration, is valid for 12 months, and governs all disturbances. The permit requires pre-exploration water quality examinations, operating requirements, plugging requirements, and site reclamation. RRC inspects active uranium exploration sites each month.	Permit	
Media-Specific Regulation						
Texas Surface Water Quality Standards	Title 30 Chapter 307 TAC	Yes	Water	Texas Surface Water Quality Standards establish quality goals, appropriate uses, an anti-degradation policy, and numerical criteria for water quality standards (dissolved oxygen temperature, pH, dissolved minerals, toxic substances, and bacteria).	Performance standards	
TCEQ Underground Injection Well Permit Program	Chapter 27 of Texas Water Code	Yes	Water; Waste	TCEQ and the RRC regulate five classes of underground injection wells. TCEQ regulates Class I, III, and IV wells. RRC regulates Class II and V wells. In situ Sodium Sulfate and Uranium operations are both required to obtain a Class III injection well permit from TCEQ. TCEQ conducts technical reviews, including reviewing the geohydrologic and engineering aspects of proposed Class III and V well facilities.	Permit; Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
TCEQ Multi-Sector General Permit (TXRR050000); TCEQ Individual Industrial Wastewater Permit (Texas Pollutant Discharge Elimination System (TPDES))	Chapter 26, 39, 40, 50, 55, 60, 80, 213, 281, 305, 307, 308, 309, 311, 319	Yes	Water	TCEQ authorizes the discharge of stormwater for certain industries with an Industrial Multi-Sector General Permit. Industries include: concrete and gypsum products, primary metals, metal mining, ore mining and dressing, and mineral mining and dressing. This permit is only issued for discharges that are in compliance with Water Quality Standards. This permit sets benchmark monitoring requirements and effluent limitations for a number of mining and processing activities, including: • steel works • blast furnaces • iron and steel foundries • nonferrous castings • rolling, drawing, and extruding of nonferrous metals. Facilities that do not qualify for a general permit, or opt not to apply, must obtain an individual industrial wastewater permit.	Permit	
Texas Hazardous Waste Regulations	40 CFR Part 26; 30 TAC 335	Yes	Waste	Texas is currently authorized to implement the RCRA Subtitle C base program, which applies to several mineral processing wastes. Texas Hazardous Waste regulations oversee permitting and monitoring of hazardous waste generators and management facilities.	Permit; Performance standards; Operational requirements	
Texas Railroad Commission surface coal mining and reclamation requirements	131.002 Texas Statutes	Yes	General	This statute regulates the reclamation of land used for minerals and surface-mining operations. It sets reclamation and maintenance requirements, including processes such as contouring, terracing, grading, backfilling, resoiling, and revegetation.	Operational requirements	

Table N. Utah: State-Level Regulations Applicable to Hardrock Mining and Mineral Processing

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
General Environmental Review Requirements						
Minerals Regulatory Program Notice of Intention	Title R647, Utah Administrative Code (UAC) (1988)	No	General	Rule R647-2 sets the standards for mining exploration. It requires a Notice of Intention to Conduct Exploration 30 days before operations begin. It requires description of project, practices, hole plugging, and reclamation practices. It also requires a description of the exploration project. Rule R647-3 regulates small mining operations. Operators must submit Notice of Intention to Commence Small (less than five disturbed acres) Mining operations 30 days before operations begin. The notice of intention must include a brief narrative description of the proposed operations. If the operator plans to enlarge the mine to a size greater than five acres, it must file a Notice of Intent with the Division. Rule R647-4 regulates large mining operations using many of the components of Rule R647-3. Additionally, the notice of intention must include an Impact Assessment (identifying potential surface or subsurface impacts), fulfillment of hole plugging requirements, and a reclamation plan. If the operator plans to enlarge the mine to a size greater than five acres, it must file a Notice of Intention to Commence Large Mining Operations, and receive approval from the Division. The rule requires annual reporting of waste	Preliminary environmental assessment	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				materials, new surface disturbances, total amount of ore and waste materials moved, and reclamation work performed.		
Media-Specific Regulation						
Minerals Regulatory Program	UAC Title R647-2; R647-3; R647-4	No	Water	These rules regulate mining exploration and operation practices. Public safety and welfare practices include the closing of shafts, disposal of waste, plugging of holes. Additionally, the rules address drainages, erosion control, deleterious materials, soil management, and concurrent reclamation. The rule also sets hole plugging requirements and reclamation practices.	Operational requirements	
Utah Ground Water Quality Protection Program	UAC Title R317	No	Water	This rule sets Ground Water Quality Standards, Ground Water Classes, Protection Level, and Ground Water Classification for Aquifers. No facility may cause ground water to exceed ground water quality standards or the applicable ground water class Total Dissolved Solids (TDS) limits. If the background concentration for affected ground water exceeds the ground water quality standard, the facility may not cause an increase over background. This requirement does not apply to facilities undergoing corrective action under R317-6-6.15A.3.	Permit	
Ground Water Monitoring Requirements	UAC Title R315-308	No	Water	This rule sets the Ground Water Quality Protection Standards. Facilities are required to perform ground water monitoring and comply with the groundwater monitoring requirements. The rule also regulates the Corrective Action	Performance standards	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				Program for owners and operators who do not successfully demonstrate that their facility meets groundwater quality standards.		
Utah Pollution Discharge Elimination System (UPDES) program	UAC Title R317-8	Yes	Water	Facilities that produce, treat, dispose of, or otherwise discharge wastewater may need UPDES permits from the Division of Water Quality. Discharging wastewater to surface waters, including storm drains, or water well drilling activities, requires a permit before beginning operations. Storm water discharge permits are required for certain construction projects, industrial facilities, and municipal separate storm sewer systems. Any facility that discharges or may discharge pollutants to ground water needs a permit. Major agricultural, municipal, and industrial dischargers are regulated. Operating Permits are required for all wastewater treatment systems, whether surface or underground, that are not operating under one of the other types of permits.	Permit	
Utah Mined Land Reclamation Act (Act) regulations	Title R647, Utah Administrative Code (UAC)	No	General	The R647, Natural Resources, Oil, Gas and Mining; Non Coal, regulations were developed pursuant to the Utah Mined Land Reclamation Act, which applies to exploration, development, and extraction of hardrock minerals on all lands, and states that every operator is obligated to conduct reclamation and is responsible for reclamation costs and expenses. (40-8-12.5).	Operational requirements	

REGULATION, PERMIT, OR REVIEW	CITATION	DELEGATED FEDERAL PROGRAM	MEDIA/ RELEASE TYPE	SUBSTANCES/ACTIVITIES REGULATED	REGULATION TYPE	NOTES
				The R647 rule sets standards for mining operation practices, which include drainage, erosion control, soil management, and concurrent reclamation. It also regulates hole plugging requirements. It further regulates reclamation practices, and provides a list of practices to minimize hazards to public safety/welfare. The mining exploration rule requires annual reporting, regarding drilling conditions, water encountered, hole plugging measures, etc. Rules R647-3 and R647-4 regulate operation practices relating to drainages, erosion control, deleterious materials, soil management, and concurrent reclamation The rule also sets hole plugging requirements and reclamation practices. Annual reporting of waste materials, new surface disturbances, total amount of ore and waste materials moved, and reclamation work performed is also required.		