Mineral Waste

Mineral waste is the solid, liquid, and airborne by-products of mining and mineral concentration processes. Although mining and metallurgy are ancient arts, the Industrial Revolution launched an accelerating global demand for minerals that has made waste generation and disposal modern industry’s most severe environmental and social challenge. Mineral solid waste production alone is staggeringly vast.

Although no accurate estimate of global waste volumes exists, estimates range from millions to billions of tons annually (depending on whether coal wastes are included), and the mining industry accounts for the largest proportion of total industrial waste production. Mine spoils are often regarded as a blight on the landscape as well as a serious environmental and public health threat. Nevertheless, mining by-products and landscapes may shift between the categories of “waste” and “value” due to changes in technology, economics, and cultural attitudes. Paradoxically massive in scope, yet largely hidden from everyday life, mineral waste is significant not only for its environmental impacts but also as a material index of contemporary rates of commodity production and consumption.

Mining Processes and Wastes

Mining entails the excavation and separation of valuable minerals from their geological matrix. In metal mining (as opposed to quarrying), since target
minerals are typically only a fraction of the ore (or mineral-bearing rock), ore processing results in considerable volumes of waste, known as tailings. A typical, modern, base-metal operation yields greater than 98 percent waste from the excavated material. These residuals are generally disposed of to the lithosphere at waste-rock dumps and tailings disposal areas (although tailings are sometimes disposed of directly to waterways or backfilled into old mine shafts). Surface materials such as soil and vegetation, removed as “overburden,” are not typically considered waste, although they contribute to mining’s environmental impact. Slag, the solid by-product of smelting, was historically left in massive piles beside smelters or dumped in nearby watercourses. Although once used as an all-purpose building and grading material, smelter slag may also contain contaminants.

Waste Hazards and Pollution
Mill waters and mine drainage are the principal liquid residuals. Because water is usually used to process ore and transport mill tailings for disposal, liquid and solid wastes are often considered together in waste-disposal planning. Environmental pollutants in both solid and liquid wastes may include heavy metals and metal salts, process reagents used to recover minerals (such as cyanide or mercury), and other contaminants in the ore (such as arsenic and selenium). Acid mine drainage (AMD) is a common and widespread water pollution problem, whereby sulfuric acid is released into the environment through the oxidation of sulfur-bearing rocks exposed during the mining process. Tailings impoundments may contribute to pollution through the overflow of contaminated water to surrounding waterways. In some instances, the catastrophic failure of tailings dams has choked streams and coated their banks with a flood of finely ground material. At their worst, tailings dam collapses have caused extensive landscape and property damage as well as human fatalities.

Many of these same pollutants are features of airborne wastes associated with mining and mineral refining. Airborne particulate matter blown from slag heaps and tailings ponds may bear harmful substances. Copper, nickel, lead, and zinc smelters were notorious for producing noxious smokestack emissions that not only affected the health of local populations but also transported pollutants over long distances, where they denuded large areas of vegetation and damaged downwind crops and livestock.

Mining has long been associated with environmental degradation. In his classic 1555 text, De Re Metallica, German doctor Georgius Agricola attempted to refute the accusations of environmental devastation leveled by mining’s detractors by insisting the waste and damage associated with mineral extraction was temporary. More recently, in the 1934 text Technics and Civilization, Lewis Mumford linked mining with the historical exploitation of both nature and humanity. For Mumford, the pursuit of minerals represented an abandonment of the organic environment for the inorganic, subterranean realm; in turn, the wastes generated by mining and metallurgy destroyed the natural world at the surface.
The problems of waste disposal and environmental degradation have made the mining industry a target of environmental critics and government regulation. For its part, the industry often resisted environmental regulations and, in many mining districts around the world, developed a reputation of disregard for local environmental and public health impacts. For instance, at the Ok Tedi Mine in Papua New Guinea, uncontrolled tailings disposal into the Ok Tedi River destroyed the local ecosystem and the livelihood of the region’s indigenous inhabitants, prompting local and international protests and subsequent court cases. In situations where ore exhaustion or financial conditions have led to mine closure and abandonment, accumulated waste materials and unsecured mine workings may continue to pose environmental hazards; the estimated millions of abandoned or derelict mine sites around the world constitute a major environmental hazard. However, large mines are by no means the only source of environmental damage. In the developing world, millions of unregulated miners engaged in small-scale, artisanal mining, generating considerable water pollution. Government and industry efforts to promote sustainable mining practices emphasize improved waste disposal, pollution remediation, and ecological restoration as critical challenges for improving the industry’s environmental record and preserving its “social license” to operate.

Impacts of Technology
In modern mining, changing technologies and mining practices have facilitated the extraction of ever-smaller fractions of target minerals and the production of an ever-increasing proportion and volume of waste. For instance, while individuals or small groups of miners associated with gold rushes and exploiting rich placer (alluvial) gold deposits moved considerable amounts of material and could significantly impact aquatic environments, the large-scale removal of such unconsolidated deposits by dredging or hydraulic cannons (called monitors) generated far greater volumes of waste. In California, hydraulic mining for gold in the 1880s instigated some of the earliest efforts to control waste from the industry, which had contributed to altered flood regimes in the state’s rivers and the siltation of San Francisco Harbor. Similarly, lode or hard rock mining proceeded from underground operations to the use of open-pit methods in order to process extensive deposits of low-grade ore. These methods were pioneered to meet the 20th century’s sharply rising mineral demand, fueled by accelerating industrial growth, mass consumption, and military needs. Historian Tim LeCain describes the resulting growth in waste production and large-scale landscape devastation as environmental “mass destruction.”

The status of mineral wastes as simply pollutants or unwanted residuals is, however, subject to change due to technological developments in ore recovery, the emergence of new mineral uses and demands, or changing mineral market conditions. In such cases, former waste may gain value, and the history of mining contains many examples of the reworking of old, apparently exhausted ore bodies or the reprocessing of waste deposits to extract valuable minerals. For instance, the legendary silver mines at Potosí in Peru were revolutionized in the 16th century by the development of the mercury amalgamation process, which enabled the recovery of silver from mineral-rich smelter wastes. Uranium is a classic example of a mineral’s sudden transmutation from waste to value: once regarded as a nearly worthless by-product associated with wildly valuable and exceedingly rare radium deposits, it was typically discarded along with mine tailings. With the discovery of nuclear fission in the late 1930s, however, stockpiled or rejected uranium-bearing ores from the Katanga in Africa and northern Canada formed the basis for the Allied nuclear weapons development program.

The notion of value in waste may be extended to the mining landscape. In some cases, what the photographer Edward Burtynsky describes as mining’s “residual landscapes” may become significant as sites of aesthetic appreciation and contested social and cultural meaning. Some observers challenge the simplistic association of mining with pollution and environmental degradation, pointing to the ways in which mining communities use, experience, and interpret the apparently “wasted” landscapes of mining. Slag heaps and tailings piles may be incorporated into local recreational or heritage landscapes or become the focus of ecological restoration and economic redevelopment activities in
Mining Law

Mining regulations and legislation have increased and changed since the early days of the industry. In Great Britain, laws regulating the ownership and operation of mines proliferated in the 19th century, and the Metalliferous Mines Regulation Act of 1872 directed the inspection, working conditions, and regulation of coal mines as well as mines of stratified ironstone, shale, and fireclay. In the late 19th and early 20th centuries, mining occurred on a much smaller scale than it does in the 21st century and therefore required less legislation. As mechanization and industrialization changed the mining industry, both state and federal governments became increasingly responsible for regulating the health, safety, and environmental aspects of mining.

Early U.S. Laws

The first mining law in the United States was passed in 1872 by President Ulysses S. Grant. Passed to promote the development and settlement of publicly owned lands in the western United States, particularly the Rocky Mountain West and Alaska, the law governs hard rock mining on 270 million acres of public-domain lands. Under the 1872 Mining Law, any U.S. citizen can freely enter public-domain lands to explore minerals, except in national parks. According to the Mining Law, once a citizen discovers a valuable hard rock mineral, that person can then establish the right to mine that mineral by staking a claim. This law continues to be in effect into the 21st century.

In 1891, Congress passed the first federal statute governing mine safety. The federal government saw the ills of child labor and prohibited operators from employing children under the age of 12. This early regulation also established some minimum ventilation requirements for underground coal mines. Congress opened the Bureau of Mines in 1919 as an agency within the Department of the Interior. The Bureau of Mines was permitted the authority to conduct research that would help reduce the number of deaths and accidents in the coal-mining industry. In 1941, the Bureau of Mines was given the authority to enter mines in order to conduct inspections and Congress passed the first codes of federal regulations for mine safety in 1947.

The 1947 act led to the federal Coal Mine Act of 1952. This legislation gave the Bureau of Mines the authority to issue violation notices and imminent withdrawal orders to companies, should their mines be found conducting work in violation of federal regulations. While there were no monetary penalties against companies at this time, the Coal Mine Act of 1952 authorized the Bureau of Mines to call for civil penalties should the Bureau find company violations.

Safety Regulation

A disastrous explosion occurred at the Consol #9 coal mine in Farmington, West Virginia, on