Water Use in Industries of the Future: Mining Industry[1]

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6.1 Mining Industry

Contributed by Jim Mavis, in CH2M HILL's Seattle, Washington, office

6.11 Structure of the Mining Industry

Mining Industry Segments

Mining in one form or another has existed since ancient times. The modern industry has evolved by incorporating gradual improvements into common practice. Mining in the United States can be classified in several ways. The classification used in this chapter recognizes four segments:

- Hard rock
- Sand and gravel
- Industrial (soft rock) minerals
- Coal

Each of these categories can be further be subcategorized; moreover, each mine or deposit has unique features. This chapter must necessarily provide only overview discussions of each major category, but acknowledges the diversity of the industry, and of deposits and methods for any one type of product.

Hard Rock

Hard rock mining produces ore for a variety of metals and minerals in the United States. Typical operations at hard rock mines, whether underground or open pit, include drilling, blasting, ore transporting and stockpiling, and, usually, size reduction.

Water use in the context of hard rock mining refers to process water that is necessary for routine functioning of the mine-mill complex, and not to incidental water such as excess mine water, accumulated precipitation, or other "nuisance" sources of water that must be dissipated. Nevertheless, incidental water, including mine water or natural precipitation, may be used for routine operation of the mine, if the mine is located in a water-short region.

Hard rock mines typically require water for drilling, and for any associated size reduction facilities. Water consumption can be stated in terms of gallons of water per ton of ore produced, except for production drilling and site dust control. For present purposes, size reduction is assumed to consist of crushing, wet screening, semi-autogenous grinding, and ball and rod mills (McNulty, pers. comm.)

Table 6.1-1 shows nominal water consumption rates for key operations at either an open pit or an underground mine.

Sand and Gravel

Sand and gravel are widely used as bedding material, in preparation of concrete mixes, and in many other construction applications. An estimated 90 percent of commercial sand and gravel is produced from "loose material." Only about 10 percent comes from hard rock. The following discussion describes water use during sand and gravel production from loose deposits.

Step 1. In a typical operation, rock less than 12 inches, long dimension, is screened through coarse bar screens ("grizzlies") and the passing material is crushed in a jaw crusher to intermediate size rock.

Step 2. Coarse-crushed rock passes through a three-level screen, and oversize material is returned to the jaw crusher.

Step 3. The smallest, sand size fraction is stockpiled for use in concrete, while the intermediate size rock fraction is either stockpiled for aggregate (nominally 1 inch and below), or is further crushed in a gyratory cone crusher.

Step 4. Crushed intermediate material is screened, and oversized material is returned to the cone crusher, or further processed in a rolling mill or a vertical impact mill, depending on product specifications.

Step 5. a. The size fraction that passes the screen drops into a tank (or vat) from which

TABLE 6.1-1
Hard Rock Mining Water Consumption

Operation	Gross Water Use, gallons per ton	Net Water Use, gallons per ton	Comments
Drilling	--	2 – 5 gpm/hole	Per-ton usage highly variable – spacing, diameter, depth, orientation, explosive type/loading
Crushing (dust control)	--	1 – 6 nominal	
Wet Screening	30 - 250	--	Gross use – once-through solids and water
Semi-Autogenous Grinding	475 – 700 nominal	125 – 200 nominal	Net use – net solids and net water makeup
Ball/Rod Mill	500 – 700 nominal	150 – 300 nominal	

sand size material (3/16 inch to ¼ inch and below) is withdrawn with a sand screw (about half of the installations). **b.** As an alternative, the fraction passing through the screen may be classified according to size in a gravity classifier (about half of the installations) to recover the sand fraction.

Step 6. Clays and silts are sent to a settling pond, from which decanted water is returned for use in the process.

Overall, a typical sand and gravel plant might produce 70 to 80 percent of its processed material as gravel and 20 to 30 percent as sand. Clays and silts normally comprise less than 10 percent of a viable loose material deposit; the settled clay mass might contain around 5 percent solids and 95 percent moisture.

Table 6.1-2 summarizes water use in a typical sand and gravel plant.

Industrial Mineral Mining

A variety of minerals are mined for use in manufacturing, in construction, and for purposes other than heating value (coal) or metal recovery. Industrial mineral ("soft rock") mining practices vary widely, according to the mineral produced and the nature of the deposits.

Two familiar examples of industrial minerals are kaolin (clay) and silica sand (used in glass making). Each is mined and processed with different methods. Kaolin clay mining and processing serve as an example. Kaolin is used

TABLE 6.1-2
Sand and Gravel Water Consumption

Operation	Gross Water Use, gallons per ton	Net Water Use, gallons per ton	Comments
Crushing (dust control)	--	1 – 6 nominal	
Wet Screening	60 – 180 nominal		
Sand Screw	~60 nominal		
Gravity Classifier	~90 nominal		
Clay Retention		1,500 – 5,000 nominal	Clays and silts retain a high percentage of moisture because of their high capillary tension

in a variety of industries, including paper manufacture, ceramics, and paint formulations. Papermaking uses a large amount of kaolin clay, and crude kaolin is not useful as a mined product until it is processed to remove impurities.

In Georgia, kaolin deposits are normally located and mapped from exploratory cores to depths typically from a few tens to about 200 feet. During mining, the overburden is stripped from one to a few acres to expose the kaolin layer. No water is used in actual drilling, but up to 1,000 gallons per core may be used in exploration and mine development.

Relatively large volumes of water are used at kaolin processing plants, which are usually located some distance from the mining area. Mined kaolin is usually slurried near the mine and transported to processing facilities through a pipeline as a clay suspension dispersed in water. Although processing methods vary with the run-of-mine clay quality and the end use for the processed clay, they usually include suspension or dispersion (deflocculation), screening, grit removal (e.g., gravity separation, centrifugation), flotation, brightening (e.g., magnetic separation, oxidation), flocculation, filtration, drying, and packaging.

Water usage varies with the specific operations needed to refine the clay for its end use, but a nominal estimate from one source indicates typical usage is ~2,000 gallons per ton of finished product. Approximately 80 percent of the finished kaolin shipped to the paper industry is in slurry form, which is 70 percent kaolin and 30 percent water.

Coal

Coal is mined in a number of areas in the United States. It is used most extensively in electrical power generation, with coke making and byproduct chemical recovery among other uses. In the eastern United States, coal is often mined underground, where risks of gas buildup cannot be tolerated. In the western United States, more coal is strip mined.

Water use in coal mining varies according to the method of mining, the equipment used, and the availability of water. Underground coal mines in West Virginia rely on the use of water for cooling the cutting surfaces of mining machinery and for inhibiting friction-induced ignition of coal fines or gas. Surface mines in the Western United States do not use water in actual mining, but they do suppress dust on haul roads with water and aqueous solutions of calcium chloride and magnesium chloride.

Statistical information about the use of water in coal mining is not available from readily accessible sources. However, one surface mine operator reported that aside from minor uses for personnel (sanitary, showers, potable), equipment maintenance, and miscellaneous uses, the overwhelming use was for dust control. Dust control consumed about 5.2 gallons per ton of coal produced. In addition, small amounts of magnesium chloride solution (~0.01 gallon of solution per ton of coal) and calcium chloride (~0.003 gallons solution per ton of coal) were used to retain moisture, since both these salts are hygroscopic (take moisture from the air).

6.1.2 Relationship of Water to Energy

Water and energy may be directly or indirectly related in the mining industry, and the connection is mainly through pumping power to transfer the water or aqueous slurries of mineral products to another location. Most mines both consume and produce water, which often must be imported for operating purposes from locations remote from the mine, or transferred as surplus mine water from within the mine to a treatment and/or discharge location. Water might also be involved in three production-related areas: mining, downstream processing, and product conveyance.

Production and Consumption

Most mines penetrate into water producing formations or fracture systems during exploration or operation. Depending on the nature of the ore and the geochemical conditions of the formation, this groundwater might either be of good quality or be contaminated to the extent that treatment is needed before discharge. Mine water must be removed from operating mines to prevent flooding, the removal rate equaling the inflow rate. Except for cases in which the mine is elevated above the surrounding topography, mine water must be pumped to a treatment system or to a discharge point. Energy consumption can be significant, not only because of large volume, but because of appreciable lift from deep within the mine to the surface, often several thousand feet.

If water is used in mining or in ore processing at a mine site, the mine water can be used for production. Some mines are water deficient, necessitating the import of water from offsite.

Mining, Processing, and Conveyance

Water use in mining operations can be divided into three categories: mining, processing, and mineral conveyance. In most types of mining, relatively little water is used in actual ore production. A notable exception is underground coal mining, where water is used as one of several measures to reduce the hazard of fires or explosions. Because of this, water and energy are related at the mine site in two ways. The rate of water use increases in rough proportion to the total energy used to operate mining machinery; since coal is mined for energy production, water use in underground coal mines might be roughly proportional to the energy equivalent of the coal. Most other types of mining use very little water in ore production, and will not be discussed in this context.

Many mined minerals are partially processed in the immediate vicinity of the mine site. The particle size of run-of-mine ore from hard rock mines often measures several inches to a foot along the longest dimension; thus particles must be reduced in size so that mineral values can be recovered in downstream processes. Water is used in crushing mainly for dust control. But screening, grinding, and milling can require significant amounts of water, depending on the scale of operation. Water use is not related directly to energy usage, but can be a function of the ore tonnage being processed, which *is* related to mill throughput. Hence, water use and energy are indirectly related.

Once ore is crushed (not needed for kaolin clay, which occurs naturally in finely divided form), the mined product can be transported through a pipeline as an aqueous slurry to a processing plant some distance away. Energy use is a function of the distance the slurry is transported, friction losses along the pipeline, and the volume and density of the slurry. Water use depends on the rheological (flow) properties of the slurry and, in some cases, the purity or contaminants in the water used to prepare the slurry. Therefore, energy is related to water use in transport of mineral products by virtue of energy required to pump mineral-containing slurries to a central processing location.

6.1.3 Water Use Practices and Challenges in the Industry

Regional climatic conditions, the type of mineral being mined, the processes being operated at the mine, and local regulatory considerations all affect whether water is viewed as a valued resource or as a nuisance that requires management and disposal. Most mining operations require at least a nominal quantity of water with which to perform critical operations such as drilling, dust control, and minimal ore processing.

Many water uses are insensitive to water quality, merely requiring a nominal volume with which to perform essential operations. Other uses, typically mineral concentration based on flotation, might dictate that certain minimum standards of quality be maintained to recover economic percentages of mineral values at sufficient grade to keep the mine profitable. A comprehensive discussion of these issues is beyond the scope of this discussion and is highly site specific.

Most mining operations reuse water to the extent possible, within constraints imposed by quality requirements, water availability, and discharge consideration. Surplus water from precipitation or from the mine is discharged, if it is not needed to operate the mine and associated crushing and grinding systems.

Transport of mineral products long distances through conveyance pipelines can cause water resources at the point of origin to become depleted, and introduce contaminants into the water during conveyance that makes the water undesirable at the final destination. This can occur with coal, for example, with the leaching of common salts, boron, heavy metals, fluoride, and other undesirable constituents. Water that accompanies coal through long-haul pipelines is not normally returned to the point of origin to be reused for additional coal shipments because of the cost of constructing a second, parallel pipeline, and because contaminants leaching from the coal would accumulate after many cycles of reuse. This controversial issue has been under study for many years in certain parts of the country, and could again warrant reevaluation in the western United States.

9.1 References

McNulty, Terry. Personal communication. November, 2002. T.P. McNulty & Associates Inc., Tuscon, Arizona.