Chapter 1

MANKIND, MINERALS AND THE ENVIRONMENT

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The Need for Minerals

Minerals have been critical to human society from the earliest and their use has been intertwined with the development of civilization. In the Western World, the mining, processing and extractive metallurgy associated with ores was first described in detail by Agricola in the 16th century. He considered these collective activities to be the most necessary and the most profitable of professions, and wrote,

> "without doubt, none of the arts is older than agriculture, but that of the metals is not less ancient; in fact they are at least equal and coeval, for no mortal man ever tilled a field without implements. In truth, in all works of agriculture, as in the other arts, implements are used which are made from metals, or which could not be made without the use of metals; for this reason the metals are of the greatest necessity to man."

Ours is still a materials-dependent society that relies heavily on minerals for raw materials. Today our dependence on minerals is exceptionally great. To meet the need for fuel and non-fuel minerals in a representative year, in the United States alone, about one billion tons of coal and 2.7 billion tons of ore are mined. These mineral products are essential for fertilizers, for construction materials, metals and alloys, for manufacturing household and industrial items, for transportation, and for the generation of electric power.

It is instructive to consider the diversity of uses found in our society for a single mineral product - silver, for example. Experts believe that in the past 5000 years we have mined about a million tons, or 31.9 billion troy ounces of silver. In 1988, 133 million troy ounces of silver were used in the Unites States. Most of the silver used was for technological, medicinal and industrial purposes, Table 1. X-ray films, for example, carry comparatively large amounts of silver to lessen patient's radiation exposure. Silver does not prevent tooth decay, but each year about two million troy ounces of silver is used for dental work in the United States. In small quantities it is used in medicine. No metal - not even copper - conducts heat and electricity so efficiently as silver. Silver wires lace solar cells, and silver oxide batteries power hearing aids, calculators, submarines and satellites. Hardened with tungsten or molybdenum, miniature discs of silver pass current from wire to wire in cars, telephones and computers. A dishwasher timer alone may have 50 such electrical contacts, which open and close without excessive heat or friction. Silver is an important component of solar reflectors, since no other material reflects light so well or uniformly. In our personal lives, silver remains in high esteem to adorn our tables, provide precious objects and jewelry. In many parts of the world, silver in the form of coins, jewelry and bullion is used for financial independence and security against the vagaries of paper currency. In India, silver is used in its purest form as thin foils to decorate sweets and other edibles. It is obvious that this mineral product, silver, is of great value and utility in our society.

Minerals and Environment

The benefits of minerals do not come without problems. Much of the silver, for example, lies locked up in copper, lead-zinc or precious metal ores; to extract it creates vast quantities of waste material. On the average, in order to recover one ounce of silver about a quarter ton of ore must be mined. To meet the world's annual demand for silver, approximately 100 million tons of waste is generated every year.

The problem with silver is repeated with all minerals. Conversion of mineral ores into usable materials necessitates the generation of large quantities of waste products that create tremendous disposal problems. In addition to waste material discarded during mining, wastes may be generated during processing as gases, liquids or solids that must be subsequently converted into forms more acceptable for disposal. Associated with the handling, treatment and management of waste products are a number of environmental problems.

Environmental problems are not new to the minerals industry. In his *Geographia*, Strabo (63 B.C. - 20 A.D.), gives an account of the conditions of labor under which men

Figure 1a. Type 1 ventilating device for directing a blowing wind down a mine shaft. At the top of the crossed vanes a round disc forces the winds F downwards into the shaft (Source: De Re Metallica).

Figure 1b. Type 2 ventilating device with a swivelling collector of fresh air to collect the breezes and send them down the ventilator pipe D (Source: De Re Metallica).

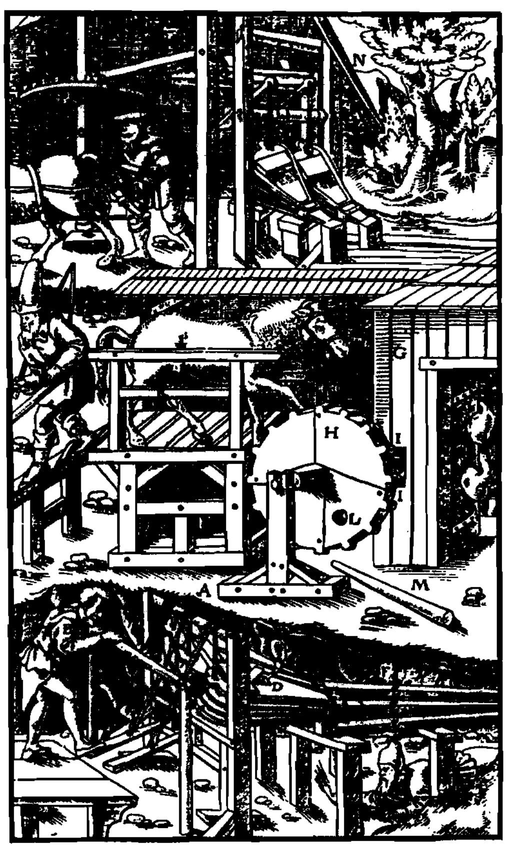

Figure 1c. Type 3 ventilating device in which bellows are used to move the air (Source: De Re Metallica).

Figure 2. Dust chamber (D) for collecting particles from the gases before they escape through the opening (E) in the chimney (F) (Source: De Re Metallica).

Table 1. Uses of silver in the United States.

End Use	Percent
Industrial Items	
Photography*	40
Contacts and conductors	19
Solders	7
Electroplating	5
Catalysts	5
Batteries	4
Consumer Items	
Sterling ware	11
Jewelry and arts	4
Coins, etc.	2
Other	3

* Both industrial and consumer uses.

worked mines in those ancient times. Strabo speaks of a mine located in the mountains of Pontus which gave strong odors destructive of life. Coal, the most abundant of the fuel minerals, was being mined before 1250 and in 1257 Queen Eleanor was forced to leave Nottingham Castle, where she was staying, on account of the objectionable smoke from the "sea coale". The smoke from burning of "sea coale" in lime kilns in London became a serious problem as early as 1285. The problem persisted, and in 1306, King Edward I compelled all but smiths to cease burning of "sea coale", the obnoxious fuel, and return to the use of wood. The *regulatory process* controlling the minerals industry had begun. In the fifteenth century, as domestic consumption increased and the industries like salt manufacture required more fuel, coal mining grew rapidly. As a *revenue* for the treasury, by this time the King had imposed a tax of 2d. per chaldron. (A chaldron was a standard measure of coal which originally was 2000 lb., but was later increased to 5200 lb. to decrease the impact of King's tax.) During Queen Elizabeth's reign the ladies of the land supported the Queen in her dislike of sea coale. Many would not enter houses in which it was burnt and thus the use of coal remained restricted under *public pressure.* Coal mining increased rapidly in the 16th century on account of the exhaustion of wood used for fuel. The problem of air pollution from burning coal reappeared by the middle of the 16th century. According to Te Brake (1975), periods of peak air pollution problems in preindustrial London correspond roughly to periods of population expansion and increased usage of mineral fuel, namely "sea coale". That is, *increased pollution is directly relatable to increased demand.* Such a statement is applicable to almost every material need, especially those involving minerals. This brief review of some historical facts shows that the minerals industry has been traditionally regulated and operated under public pressure. In spite of these limitations it has contributed to the benefits of nations and humanity.

The Minerals Industry and Pollution Control Technologies

Pollution control methods have been practiced in the minerals industries for centuries. The technology of *ventilation, dust collection* and *recycling* was being used before Agricola described them in his treatise, *De Re Metallica*, in the 16th century. He laid out various means for bringing fresh air to the miners, Fig. 1a-c. The first device consisted of crossed baffles set in the center of a shaft to catch and deflect a passing wind downward; the second type was more complex with a barrel mounted to turn in the horizontal plane so as to catch the passing breeze and force it down the pipe set into the mining shaft; and the third device was a blowing machine made with bellows and powered by man, animals, wind, or water.

Dust was another matter of concern to Agricola. Technology for capturing dust existed by the 16th century, and he describes the use of vaulted dust chambers such as those shown in Figure 2. Fumes rise from the furnaces through two openings into the wide vaulted chamber; the wider it is the more fumes it collects. The chimney in the dust chamber had thin iron plates fastened into the walls, to which the thinner metallic substances adhere when ascending. Suppression of dust in mines by water was described by Raymond (1879-80) who states, "...where the coal is kept damp by the percolation of water, little dust is made, and the miner is comparatively free of its injurious effect...."

Acid mine drainage in coal fields results from the oxidation of pyrite associated with coal seams. In the early part of this century, many miles of streams were polluted with these acid waters in Pennsylvania. To solve this problem, in the 1960's, Dr. H. B. Charmbury, then Secretary of Mines of the Commonwealth of Pennsylvania, put into action "Operation Yellowboy" a portable treatment plant which travelled the state, visited over 100 acid mine drainage sites and developed the technical and economic data needed to develop effective treatment procedures. Such an approach was necessary since the drainage from each mine often represents a different treatment problem. As a result of this pioneering work, and the development under Dr. Charmbury's supervision, of effective control measures, acidic mine waters from all operating mines in the state are now treated.

These historic examples illustrate the fact that the Mineral Industries have centuries of experience in dealing with problems of environmental hazard and pollution control. Over the years technologies have been developed to handle bulk waste, process water, air quality, dust and toxic substances in many situations. The technologies developed by scientists and engineers for minerals and metal processing have become the main source of today's pollution control techniques in a wide range of modern industries. For example, the bag house used extensively in air pollution control was originally developed to collect valuable dusts from non-ferrous processes. The electrostatic precipitator, first used commercially in 1914 to collect dusts from a lead smelter in Selby, CA and later used in many non-ferrous smelting operations, now finds its greatest use in collecting fly ash from the majority of fossil fuel-fired power plants. The thickener developed early in the century at the

Lindberg, Don and Wilson Mill in Terry, SD for gold cyanidation is now an integral part of many potable water and sewage treatment plants. More recently, the treatment of toxic wastes, as at Superfund sites, uses a broad variety of mineral processing techniques such as gravity concentration, classification, foam fractionation, adsorption and hydrometallurgy.

We can also anticipate that the recycling of materials, which will undoubtedly become more and more essential to the functioning of society, will also involve the use of separation methods developed by mineral processing scientists and engineers. The current technology employed in this fledgling industry is now at the level of the handpicking operations used in the earliest mineral processing operations.

The mineral process engineering profession plays a key role in maintaining an adequate supply of vital commodities at affordable prices. The education of mineral processing and extractive metallurgical engineers is highly appropriate to many of the needs for environmental remediation. Classical mineral processing and hydro- and pyro-metallurgical methods plus particle technology (creation, characterization, separation, agglomeration) and applied surface chemistry (flotation, foam fractionation, flocculation, dispersion, filtration, etc.) provide an ideal framework to analyze and remedy environmental problems.

Future Outlook

Minerals industry is likely to continue to be responsive to the future needs of the society, as it has done in the past, but several changes would be essential. To meet the future demand for raw materials, minerals will have to be recovered from exceedingly low grade ores, under strict environmental regulations, and tight economic and energy constraints. Minerals-related pollution problems will increase with lower grade ores because increased amounts of waste will be generated even if the demand for minerals is maintained at current levels.

Since stringent regulations, designed to assure a cleaner environment, tend to limit development, and an adequate supply of mineral raw materials is linked to economic growth, the future economic strength of the nation will depend on a balance between the two. The balancing task is not simple but would require complex interactions among the governmental, political, social, cultural and industrial segments of the society.

We can learn from past experiences which show that strict regulation has resulted in periods of short supply leading to economic recessions. Recent trends are disturbing. In the United States, the total tonnage of metalliferous ore mined has decreased in recent years; but, at the same time, reliance on other countries for supply has grown. The increases have been through direct import of minerals or through indirect import of mineral-based products. These are not very healthy signs because both the trade deficit and dependence on foreign countries have increased. In addition, the minerals industry is no longer driven by the best technology. A large number of often conflicting regulations, promulgated by various agencies such as OSHA, MSHA, NIOSH and EPA ("Interview with T. H. Eyde....", Mining Engineering, March 1991), have given a secondary role to technology. The task of complying with environmental regulations has become so great that today many companies consider environmental issues, rather than productivity, as their top priority.

The domestic minerals industry faces additional difficulties due to stiff competition from other countries where ores are richer and easier to process and the environmental regulations are lenient.

Unless new mineral resources are explored and developed, periods of increased demand and short supply will lead to an increase in the cost of minerals-related consumer items which might again begin the growth cycle for the minerals industry. Such periods have often occurred, stimulated by periods of eased regulation to achieve growth.

Meanwhile, to stimulate economic growth, while still conserving national mineral resources, a multi-pronged approach will be necessary. The nation will either have to reduce consumption or increase efficiency of utilization. Simultaneously, steps will have to be taken to minimize the quantity of waste generated. Although technological developments could, in principle, reduce reliance on the production of those minerals that produce pollution, such developments are few and far between. For example, coal has for centuries been used as a source of energy, and even now, to obtain energy, in the United States approximately one billion tons of it are burned annually. Furthermore, to preserve the high environmental quality, process modifications will be needed to produce environmentally acceptable waste and to prevent the release of toxic waste at the source. Recycling will invariably be involved, and the use of minerals processing and extractive metallurgy unit operations will provide the means to do so. To achieve these goals, technological developments are essential. Unfortunately, the level of R&D in the minerals industry has diminished in recent years; steps will be needed to reverse this trend.

More than a hundred years ago, R. W. Raymond (Transactions AIME, Vol. VIII, 1879) stated, "It is cause for congratulations that the improved state of science and the requirements of mining laws in all civilized countries have greatly improved the conditions of the mines....." I would like to end this article with a note that all concerned, namely, the minerals industry, the regulatory agencies and the public must continue to interact in a manner which gives a positive reinforcement to the development of the national minerals industry that is so vital to economy of the nation.

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