fire was brought indoors to heat caves or shelters, the problem of smoke exposure became more severe, and at least some additional ventilation usually had to be provided in order to enjoy the benefits of the fireplace. However, success in this regard was only partial; mummified human lungs from the preindustrial age show considerable carbonaceous pigmentation. Dwellers in heated caves were undoubtedly exposed to significant levels of carbon monoxide and polycyclic aromatic carcinogens as well as black smoke.

In calling things "clean," "dirty," "contaminated," or "polluted," we are using terms that are subjective or, in specific contexts, have arbitrary meanings. Thus, a human environment can never be absolutely clean because, by definition, it includes at least one contaminant source, a person. An environment passes from clean to contaminated when the source of contamination, relative to its rate of elimination, is sufficiently large, or where there are enough sources whose aggregate output is sufficiently large, to exceed some sensory or predetermined physical concentration limit that is considered acceptable. Thus, practices that are environmentally acceptable in rural areas, such as setting wood fires, discharging sanitary waste liquids into septic tanks or underground drainage fields, and unleashing pet dogs, can become unacceptable in densely populated urban regions.

The degree of environmental contamination that a society finds acceptable is highly variable in both space and time, and depends more on the rate of change in contaminant levels than on their absolute amounts. It also depends on whether there appears to be a realistic alternative. Very high levels of soot from inefficient coal combustion were tolerated for centuries, as long as cleaner combustion alternatives were not available at prices deemed reasonable and the alternative was being cold or worse.

With the large-scale conversion of heating and electric utility boilers to oil and gas combustion in recent decades, there has been a major reduction in sulfur dioxide, dustfall, and suspended airborne particulate matter. As we continue to utilize our vast coal resources in the coming decades, it is not likely that our more affluent and environmentally aware society will permit significantly increased levels of contaminants. We therefore have to pay for the alternate fuels and/or install control technologies needed to prevent the release of air pollutants and greenhouse gases from coal combustion.

Public acceptance of environmental contamination also depends on whether it is perceived to be "natural." Fire and its effluents have been part of the human environment throughout recorded history. Thus, the potential health effects of inhaled combustion products create relatively little concern, even though these effluents contain many readily detectable toxicants.

On the other hand, the nuclear power industry has kept most discharges of radioactive waste products to a very low level, and produces electric power without generating any of the chemical toxicants cited above or carbon dioxide, the major greenhouse gas. But many people prefer greater reliance on fossil fuel–fired power plants than on nuclear-power plants because they associate nuclear power with catastrophic releases of radionuclides, as from the Chernobyl reactor failure, and with bombs, and equate exposure to radioactive wastes with cancer. The fear of bombs and cancer, in effect, leads to public acceptance of increased dependence on fossil fuels, even when their currently documented adverse effects on human health and environmental quality can be shown to be much greater than those from the operation of nuclear power plants.

Similar considerations apply to food safety. Under the Delaney clause of the Food and Drug Act, which was adopted in 1958 and not repealed until 1996, a variety of food additives, colors, and packaging materials were banned because they were demonstrated to have the potential of causing cancer in laboratory animals when administered in high doses. On the other hand, many natural foods contain carcinogens and other toxicants of equal or greater potency, yet neither the Food and Drug Administration nor the general public has shown much interest in banning their distribution.

If the reader is confused about the effects of chemical contaminants on environmental quality and human health, it is not surprising since many reports in the popular media are selective with respect to content and emphasis, the information is fed directly or indirectly to the media for the purpose of advancing a particular viewpoint. In our incomplete state of knowledge about most environmental issues, it is relatively easy to provide plausible documentation for either the pro or con side of almost every issue.

HISTORICAL BACKGROUND

One of the earliest written discussions of the relation between environment and health was the Hippocratic essay *On Airs, Waters and Places,* written around 460 B.C. It advised physicians to consider the winds, seasons, and sources of water when evaluating the health of their patients. Hippocratic works also described lead colic in miners, as well as diseases occurring in other occupational groups.

Other authors of ancient Greece and Rome recognized that some of the materials used in metallurgy were toxic. Pliny the Elder discussed the dangers in handling sulfur and zinc, and Galen recognized the dangers of acid mists among copper miners. Although the ancients were not aware of the possibility, subclinical chronic lead poisoning may have been widespread. Leaded glazes were widely used on kitchen pottery, and acidic wines and foods extracted some of the lead. The Romans also used lead pipes for the delivery of drinking water, and some of the lead was slowly dissolved into the water. The exposures would have been greatest among the more prosperous Romans, who more often had running water and glazed vessels. The decline of the Roman Empire has been partially attributed by some to chronic lead intoxication, on the basis that the recorded decline in fertility among the upper classes was consistent with the effects of ingested lead.

Occupational Diseases

The association between exposure to chemical contaminants and human health effects has been made most often for people with occupational exposures, where the levels of exposure are generally higher than for the general population. Treatises on occupational diseases began to appear in Europe in the Middle Ages. In 1472, Ulrich Ellenbog of Augsburg wrote an eight-page booklet that discussed the toxic actions of carbon monoxide, nitric acid vapors, lead, mercury, and other metals.

A classic description of mining technology and its hazards, *De Re Metallica,* was published in 1556 by the heirs of Georg Bauer, a native of Saxony who was more commonly known by his Latin name of Georgius Agricola. From 1526 to his death in 1555, Agricola had been the official physician of the Bohemian mining town of Joachimstal, a major source of European silver, and more recently of radium and uranium. The silver coins of Joachimstal were known as Thalers, which in English later became dollars. *De Re Metallica* is a scholarly work of 12 books. It was translated from Latin into English in 1912 by an American mining engineer and his wife. (The engineer, Herbert C. Hoover, eventually gave up engineering for public service and was elected President in 1928.) In the last part of the sixth book, Agricola described diseases of the lungs, joints, and eyes that were common among the miners. It appears from descriptions of the diseases that the men had silicosis, tuberculosis, lung cancer, and combinations thereof. The book also contained numerous woodcut illustrations. Figures 1–1 and 1–2 show samples that illustrate means that were used to limit hazardous exposures.

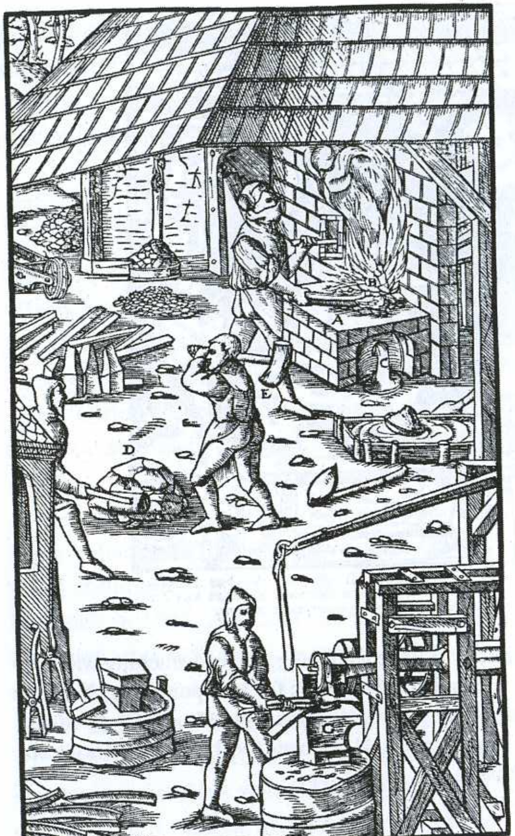
In 1567, a posthumous work appeared with the title *Von der Bergsucht und anderen Bergkrankheiten* (On the Miners' Sickness and Other Diseases of Miners). It was written by Theophrastus Bombastus von Hohenheim, better known as Paracelsus, an itinerant physician and alchemist of Swiss descent. This monograph was devoted to the occupational diseases of mine and smelter workers. Paracelsus did not consider dust exposure to be the causative factor in the lung diseases he observed in miners, but rather explained them in terms of alchemy and the stars. He was considerably more astute in his description of the diseases among smelter workers, however, and differentiated between acute and chronic poisonings. His detailed descriptions of mercurialism covered most of the currently recognized symptoms. Paracelsus is also well-known for his enunciation of a basic tenet of toxicology: "All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy."

A—Furnace. B—Sticks of wood. C—Litharge. D—Plate. E—The foreman when hungry eats butter, that the poison which the crucible exhales may not harm him, for this is a special remedy against that poison.

Figure 1–1. Woodcut from Agricola, Book X. The technology of lead smelting was considerably more advanced than the recommended prophylaxis for lead poisoning. Note the barrier plate, D, which protects against splatter burns. (*Source*: Agricola, G. *De Re Metallica,* Basel, 1556. Translated by H.C. Hoover and L.H. Hoover for the *Mining Magazine,* London, 1912. Reprinted by Dover Press.)

The most comprehensive description of occupational diseases of its time, and for well over a century thereafter, was a book of 40 chapters entitled *De Morbis Artificum* (Diseases of Workers), published in 1700 by an Italian, Bernardino Ramazzini, a professor of medicine at the University of Modena and, after 1700, at the University of Padua. Ramazzini is the generally acknowledged "Father of Occupational Medicine." His descriptions of diseases covered most of the trades practiced in his time, including those of dirty and humble trades, such as corpse carriers, porters, and laundresses. He stated: "When a doctor visits a working-class home he should be content to sit on a three-legged stool, if there isn't a gilded chair, and he should take time for his examination; and to the questions recommended by Hippocrates, he should add one more—What is your occupation?" Unfortunately, there is still a great deal of unrecognized occupational disease today because too many physicians still neglect to ask that important question.

Hazardous working conditions and occupational diseases were also common in the more technologically advanced countries in Asia. Extensive descriptions of the operations involved in the mining and refining of metals were provided in the *Atlas of Important Products in Mountains and Sea of Japan* (1754), and



A—Hearth. B—Heap. C—Slag-vent. D—Iron mass. E—Wooden mallets. F—Hammer. G—Anvil.

Figure 1–2. Woodcut from Agricola, Book IX. Note respiratory protection of the furnace worker. (*Source*: Agricola, G. *De Re Metallica,* Basel, 1556. Translated by H.C. Hoover and L.H. Hoover for the *Mining Magazine,* London, 1912. Reprinted by Dover Press.)

Atlas of Mining and Refining of Copper (1801), and are illustrated by woodcuts, such as the one reproduced in Figure 1–3.

In 1775, an English physician, Sir Percival Pott, provided the first description of occupationally induced cancer, that of scrotal cancer in chimney sweeps.

In 1831, Charles Turner Thackrah made a special contribution to this era by the publication of his 200-page book, *The Effects of Arts, Trades and Professions and All Civic States and Habits of Living on Life and Longevity,* based mainly on his experience in the manufacturing district of Leeds, England.

Scattered reports on occupational diseases appeared in the British, French, German, and American literature through the balance of the nineteenth century. Before the end of that century, it was clear that it was desirable to anticipate problems associated with industrial exposures to toxic chemicals before they happened, rather than after their effects were apparent in workers, and that this could usually be accomplished through the systematic exposure of laboratory an-

Figure 1–3. The refining of copper in the Besshi Copper Mine in Japan, circa 1800. [*Source*: "Atlas of Mining and Refining of Copper, 1801," Reprinted in: Miura, T.A. Short History of Occupational Health in Japan (Part I). *The J. of Science of Labour* 53:509–25, 1977.]

imals. Pioneering work along these lines began in the 1880s under K. L. Lehmann in Wurzburg, and by 1884 he had published data on the results of toxicological studies with 35 gases and vapors.

With the rapid growth in industrialization in the nineteenth century, more and more workers were being exposed to a broadening spectrum of toxic materials at increasing concentration levels. The obvious effect was a great increase in occupational disease and disability. This was first apparent in England and, by 1833, the first of the English Factory Acts was passed by Parliament. They established the principle that people injured at work are entitled to compensation. While there was no requirement to prevent the conditions that led to the need for compensation, it became more profitable for many businesses to reduce the compensation costs through preventive measures rather than through paying claims. The need for positive preventive measures was recognized later, and the English Factory Act of 1878 created a centralized Factory Inspectorate. Most of the major European countries followed the British lead, but it wasn't until 1911 that Wisconsin became the first U.S. state to establish workmen's compensation, and not until 1948 that the last one did so. The first state programs to inspect industry for occupational exposures began in 1913 in New York and Ohio, but nationwide coverage was not achieved until the passage of the federal Occupational Safety and Health Act of 1970.