Asbestos Revisited

Once considered safe enough to use in toothpaste, this unique substance has intrigued people for more than 2,000 years

by James E. Alleman and Brooke T. Mossman

The future for asbestos appears downright grim. After two decades of horrendous headlines, this strange fiber probably represents the most feared contaminant on the earth. It is almost certainly the most expensive pollutant in terms of regulation and removal. This year alone, remediation efforts will cost several billion dollars—a staggering outlay, even for an era of enthusiastic environmental activity. Clearly, chaos has come to the world of asbestos. The magnitude of the crisis, however, clouds a crucial irony: the problem with asbestos would never have grown so bad had we not previously thought the material was so remarkably good.

The asbestos label actually applies to a family of silicate minerals, containing silicon and oxygen, that are notable for their fibrous structure [*see box on page 73*]. Seemingly blessed with useful attributes, such as softness, flexibility and resistance to fire, asbestos was once seen as the silk of a magic mineral world. Over the centuries, people have woven asbestos cloaks, tablecloths, theater curtains and flameproof suits for protection against fiery dangers. Asbestos insulation products not only saved energy but also shielded workers from potential burns. Brake shoes and clutch facings improved safety on race cars and school buses; efficient asbestos air filters were used in hospital ventilators, cigarette tips and military gas masks. Indeed, a poignant paradox of the asbestos story stems from its previous image as a guardian of human safety.

The first references to asbestos can be traced to several ancient philosophers. One of Aristotle's students, Theophrastus, probably deserves credit for the original citation in his classic text, *On Stones,* written around 300 B.C., in which he referred to an unnamed substance resembling rotten wood that, when doused with oil, would burn without being harmed. Over the next four centuries, various Greek and Roman scholars added successive insights on this unusual rock and its ever expanding uses. In the first century the geographer Strabo identified the first Greek asbestos quarry on the island of Évvoia, where fibrous stone threads were combed and spun like wool to make an assortment of flame-resistant cloth items.

The Greek physician Dioscorides, in his first-century text *De Materia Medica,* reported that reusable handkerchiefs made of asbestos sold to theater patrons were cleansed and whitened with fire. Dioscorides' work also described an asbestos quarry on Mount Olympus in Cyprus and provided the first mention of the mineral's name: *amiantus,* meaning "undefiled," to reflect its resistance to fire. At least three other authors, including Plutarch, indicated that the eternal flames in the Acropolis were created with asbestos lamp wicks.

The informative account given in Pliny the Elder's first-century manuscript *Natural History* includes one of the most thorough discussions of the stone written in its early history. The mineral's current name can be traced to this text: Pliny referred to *asbestinon,* meaning "unquenchable." According to Pliny, asbestos was used in a number of woven products, from easy-to-clean tablecloths

The Ups and Downs of Asbestos's Past

First mention of asbestos appeared in the Greek text *On Stones,* written by Theophrastus, one of Aristotle's students. Theophrastus referred to a substance that resembled rotten wood and burned (*right*) without being harmed when doused with oil.

300 B.C.E.

Dioscorides' *De Materia Medica,* a first-century medical text, described reusable handkerchiefs made of asbestos that could be cleaned and whitened with fire.

Pliny the Elder referred to the substance *asbestinon* in his book *Natural History.*

50 C.E.

DRAWING OF PIPE BY BRYAN CHRISTIE; ASBESTOS SAMPLE COURTESY OF MALCOLM ROSS; JASON GOLTZ (*photograph*)

and napkins to shrouds for deceased royalty placed in funeral pyres (the bodies would be incinerated by the heat even though the shrouds did not burn).

Over the next 1,000 years, asbestos continued to attract the attention of kings and chemists from western Europe to China. Even the Vatican laid claim to an asbestos burial gown reportedly found in an ancient Roman sarcophagus. Somewhere along the line, though, the fact that asbestos was a stone seems to have been forgotten.

A considerable amount of fantasy was attached to the possible source of the extraordinary fibers. Medieval alchemists started this trend with a rumor that asbestos grew as hair on fire-resistant salamanders, lending still another name, *salamandra,* to the stone. Works of alchemy frequently incorporated the imagery of an omnipotent salamander surrounded by flames. In the early 16th century France adopted this symbol as a royal emblem on flags, coins and fireplace mantles. (The French first took an interest in asbestos some 700 years earlier, when, according to popular legend, Emperor Charlemagne set an asbestos tablecloth on fire to intimidate his dinner guests.)

The salamander myth was just one of many. Lizard plumes and bird feathers were, for a time, each considered to be the source of asbestos. Attempts to define these fibers led to a bizarre system of nomenclature: several dozen names were eventually assigned to the different forms of asbestos, including "mountain leather," "incombustible linen," "rock floss" and "feathered alum."

Marco Polo serendipitously brought asbestos back to the realm of science. Writing in his diary after visiting a Chinese asbestos mining operation in the late 13th century, he completely debunked the salamander theory and pegged asbestos as a stone. Georgius Agricola, one of the founders of mineralogy, provided a critical boost to the scientific understanding of the substance in the 16th century with his publication *Textbook of Mineralogy.* After carefully reviewing and updating information about the various types of asbestos, its sources and uses, Agricola offered an unusual insight: one of the very few researchers to employ an asbestos taste test, he cautioned his readers that it might "sting the tongue a little."

Asbestos Trade

In 1660, when England chartered the Royal Society, the world's scientific community was becoming increasingly fascinated by asbestos. The society published a series of eight reviews and letters on asbestos over the next 40 years. Later, in 1727, Franz E. Brückmann, a German mineralogist, wrote the first full volume on the topic; similar publications from two other leading scientists of the time, Martin F. Ledermüller and Torbern Bergman, soon followed. Ledermüller's publication was a cutting-edge treatise, depicting each of the known types of fibers with detailed colored engravings.

The range of commercial applications grew with each new publication. Fireproof coats, shirts and sleeve ruffles joined the original group of cloth items; there was also talk of making an indestructible "Book of Eternity," printed with gold on asbestos paper. Credit for another use belongs to a young inventor, Benjamin Franklin. While still a teenager, he carried a small purse woven from asbestos fiber, allegedly hoping that its contents wouldn't burn a proverbial hole in his pocket. During Franklin's first trip to England in 1724, he sold the purse to the British Museum's eventual benefactor, Sir Hans Sloane. (The purse is now in the Natural History Museum's collection.)

Even a group of devious entrepreneurs managed to earn a lucrative living during the late 1700s and early 1800s by exploiting the properties of asbestos. The most successful of these scoundrels were at the same time the most unscrupulous, selling false artifacts to a gullible audience of religious patrons. Cloth and wood relics, presented as miraculous, fire-resistant remnants of Christ's robe or cross but actually made of asbestos, were among the most popular. In a somewhat more innocent practice, a band of traveling stuntmen used fireproof asbestos gloves and capes to mystify audiences during their fiery shows. Another group, known as the Human Salamanders, was particularly famous for roasting handheld steaks while standing inside a bonfire.

In the 1820s a prominent Italian scientist converted this daredevil trick into the first truly successful asbestos business. Giovanni Aldini's ready-to-wear line of fireproof apparel, designed specifically for urban firemen, drew rave reviews and rapidly attracted clients from Paris to Geneva. Shortly thereafter, asbestos proscenium curtains began to

TOMO NARASHIMA

Vestal virgins (*left*) guarded the eternal flame at the shrine of Vesta, goddess of the hearth; the lamp's wick was made of asbestos.

Around the year 800, Charlemagne threw an asbestos tablecloth into the fire and pulled it out again unharmed in an attempt to impress some of his dinner guests.

COURTESY OF THE BRITISH LIBRARY

The hairs of fire-resistant salamanders (*left*) were considered to be the source of asbestos fibers by some medieval alchemists.

Marco Polo visited an asbestos mine in China during the latter half of the 13th century. He concluded that asbestos was a stone, not the hair of a woolly lizard.

100

1000

1500

1800

1820

1850

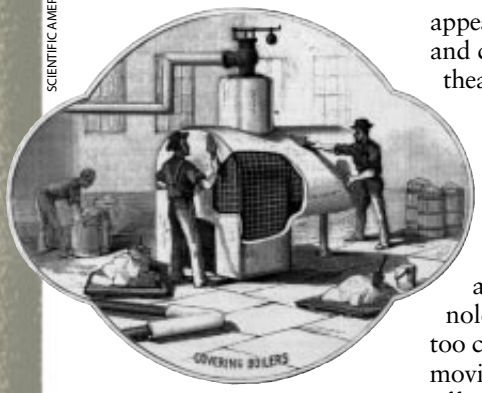
1828: First known U.S. patent for asbestos, issued for insulating material in steam engines
1834: U.K. patent for use of asbestos in safes
1853: U.K. patent for asbestos in lubricants used for bearings

SCIENTIFIC AMERICAN

Roofing felt made of asbestos

1859: U.K. patent for asbestos-lined fireboxes
1865: U.K. patent for asbestos insulating material for electrical wires
1868: U.S. patent for roofing felt made of asbestos

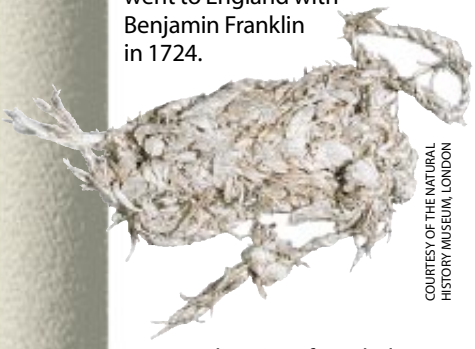
SCIENTIFIC AMERICAN



Asbestos used as insulating material

Fireproof apparel and theater curtains began to appear across Europe in the early part of the 19th century.

Purse made of asbestos (*below*) went to England with Benjamin Franklin in 1724.



COURTESY OF THE NATURAL HISTORY MUSEUM, LONDON

Royal Society, founded in England in 1660, published some of the first scientific papers about asbestos in the journal *Philosophical Transactions*.

Textbook of Mineralogy, written by Georgius Agricola in the 16th century, included a lengthy description of the properties of asbestos and where it could be found in places such as Greece, India and Egypt.

appear, installed to enhance stage safety and credited with saving many lives in theater fires.

It was the steam engine, though, that made asbestos a superstar stone. These massive machines had been steadily pushed to their physical limits; further improvements in safety and efficiency awaited some breakthrough in technology. Asbestos alone tended to be too coarse and abrasive for the engine's moving parts. But mixed with rubber, it offered just the right combination, allowing workers to make more resilient internal components, such as steam gaskets and packings.

By the 1860s the use of asbestos had literally hit the roof. After dabbling in fireproof paint mixtures, a young New York building contractor, Henry Ward Johns, developed a flame-resistant tar paper tailor-made for an era all too frequently plagued by building fires. This roofing material, which blended asbestos fibers into a tar, burlap and manila paper sandwich, paved the way for an immense industry in asbestos-based construction products.

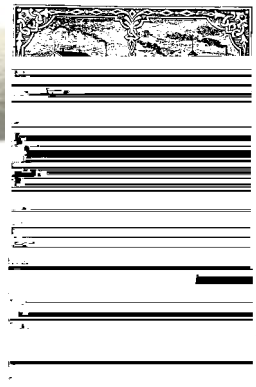
Mixtures of asbestos and cement were first used in building materials shortly after the turn of the century, beginning with a lightweight, high-strength construction panel invented by an Austrian engineer, Ludwig Hatschek. Once again, because of the intense concern about fire protection, Hatschek's invention created an overnight sensation. Other workers soon derived several related products from Hatschek's basic formula, including synthetic slate roof shingles, corrugated wall and roof panels, and decorative wall and ceiling moldings.

Dozens of products introduced in the first half of this century incorporated asbestos. Fireproof ships were constructed out of boards of asbestos and cement. Blends of plastic and asbestos were used in buttons, telephones and electrical panels. Indeed, from its start, the plastics industry relied on the combination of plastic and asbestos; the fibers strengthened the mix, reduced weight and improved thermal resistance. Even after more advanced polymer materials began to dominate the market, asbestos remained an important binder and strengthening agent. Vinyl-asbestos tile, for instance, became a mainstay of the flooring industry. To this day, automobile brake shoes that contain asbestos are sold in repair shops around the country by mechanics unconvinced that a perfect replacement has been found.

Asbestos Man

By 1939 the public's perception of asbestos could hardly have been more positive. That year the New York World's Fair included a prominent display from the company Johns-Manville that proudly celebrated the mineral's "service to humanity." A giant Asbestos Man greeted visitors to the company's pavilion and offered a thorough indoctrination about the extraordinary traits of asbestos. The fair itself was literally draped with asbestos, from rooftop coverings to underground pipelines.

After this wave of popularity just before World War II, the demand for asbestos was on the verge of surpassing the global supply. Lacking adequate domestic reserves, the world's military superpowers found themselves heavily reliant on foreign imports. The Germans attempted to amass an adequate stockpile, covertly shipping supplies from South Africa. For a time, the Allies feared that Germany had devised a chemical substitute, although subsequent top-secret Central Intelligence Agency studies disproved these rumors.



UNIVERSITY OF DELAWARE LIBRARY, NEWARK, DEL.

Advertisement for asbestos from the 1870s

1880

1884: U.K. patent for asbestos construction boards
1885: U.K. patent for asbestos membranes used to filter substances such as juices

BASS PHOTO COMPANY COLLECTION, INDIANA HISTORICAL SOCIETY LIBRARY

The Indiana State Capitol (*left*) was mentioned in an 1894 advertising booklet for uses of asbestos entitled "Heat Insulation and Fire Protection in Prominent Buildings."

In this country, foreign sources of asbestos—such as the exchange program set up between the U.S. and the Soviet Union by the American entrepreneur Armand Hammer and the Soviet leader Vladimir Lenin—were considered dangerously vulnerable. While Canadian mining operations tried valiantly to meet American demands, the government imposed severe nationwide restrictions on nonessential applications. Several hundred tons had to be supplied every day for uses ranging from ships' engines to auto parts for army jeeps. Parachute flares, bazooka shells and torpedoes all carried asbestos; battlefield medics even used it as an easily sterilized surgical dressing.

The global boom in construction after World War II triggered the next, and probably last, asbestos rush. Structural engineers clearly valued the strength, durability and fireproof nature of asbestos-cement products and liberally worked them into their designs. High-rise buildings became a reality in part because of an innovative spray-on asbestos coating that protected steel structures against fire-induced buckling.

The unusual properties of asbestos led to an absolutely startling range of uses. The U.S. Postal Service had it woven into fireproof mailbags. Fruit juice, wine and sugar producers purified their goods with asbestos filters. Heart surgeons used it for thread, and a toothpaste was

What Is Asbestos?

Six distinct types of asbestos have been identified: actinolite, amosite, anthophyllite, crocidolite, tremolite and chrysotile. All contain long chains of silicon and oxygen that give rise to the fibrous nature of the mineral. Yet each is decidedly different in physical and chemical properties, depending on the other components of the rock, such as calcium, magnesium or iron.

The fireproof threads of asbestos are stronger than steel and quite resilient, making the stone appealing for a wide range of industrial applications. Yet the strength and resilience of asbestos also make it dangerous to human health. Asbestos fibers can penetrate bodily tissue, particularly the lungs, eventually causing tumors to develop.

The first five versions listed above (the so-called amphibolic versions) are by far the strongest and stiffest—thus making them the most dangerous. The two most common amphibolic types, amosite and crocidolite (often referred to as "brown" and "blue" asbestos, respectively), originate in remote South African mines and were once mixed with insulation and cement until regulations were enacted prohibiting the use of amphibolic asbestos. The remaining amphibolic versions—anthophyllite, tremolite and actinolite—were never commercially significant.

The sixth type of asbestos, chrysotile, once accounted for more than 95 percent of the asbestos used worldwide. Chrysotile differs significantly in texture, composition and behavior from the other forms of the mineral. Its crystal structure is snakelike (hence its alternate name, "serpentine"), and it is noticeably softer and more flexible than the other kinds. Because chrysotile is softer and can be broken down by the body more easily than the other forms, it does not damage tissue as extensively as the five amphibolic varieties.

CHRYSOTILE

CROCIDOLITE

AMOSITE

An estimated 20 percent of buildings in the U.S. still contain products such as shingles, cement pipes and insulation made from chrysotile asbestos. Yet well-maintained asbestos in buildings will not spontaneously shed fibers into the air. Instead decay, renovation or demolition of the structures can lead to the release of fibers. Furthermore, most studies indicate that airborne levels of asbestos in buildings—even those in which the original asbestos has been disturbed—are significantly lower than current health standards set by the U.S. government to protect asbestos workers.

—J.E.A. and B.T.M.

JOHN A. UNDERWOOD *Purdue University*

Lady Asbestos, from an early 20th-century advertising booklet

Telephones and various other household items were fabricated from a blend of asbestos and plastic.

Asbestos Industry Regulations were passed in England in 1931 to address concerns that exposure to asbestos led to lung damage, particularly among textile factory workers.

Automobile brake shoes were made of asbestos.

Asbestos Man (*right*), from 1939 World's Fair

made with its fibers. Modeling clays and artificial snow contained asbestos. Hollywood even gave the mineral a couple of bit parts, in the Wicked Witch of the West's burning broomstick in *The Wizard of Oz* and the man-made spider webs that hung across the reanimated ancient Egyptian's cave in *The Mummy.*

Escalating Health Concerns

By the time the U.S. Environmental Protection Agency opened its doors in 1970, the commercial world of asbestos had expanded into thousands of products. Annual use in this country continued to climb for another three years, hitting an all-time high in 1973 of nearly a million tons. But shortly thereafter, the history of asbestos took a negative turn, driven by escalating concerns about human health.

Problems stemming from the inhalation of exceedingly high levels of asbestos in milling and manufacturing plants had actually been observed since the turn of the century. Reports of fibrotic lung damage, known as asbestosis, in Britain's dusty textile factories led to that country's enactment of the Asbestos Industry Regulations of 1931. Over the next several decades, however, the topic drew relatively little attention from the emerging industrial health field, despite the fact that medical investigators had also uncovered a worrisome link between asbestos and lung cancer, especially in smokers.

This mood started to change during the mid-1960s as it became apparent that even low levels of asbestos posed significant health hazards; this finding implied that much larger numbers of people, including thousands of World War II–era ship insulators, might be at risk for lung damage. Disturbing results from around the world fingered the class of asbestos known as amphiboles as the principal culprits for inducing mesothelioma, a tumor found in the chest or gut. In response to these revelations, most industrial countries imposed regulations that limited exposure to just the amphiboles. But faced with increasing pressure from labor unions and ominous projections of a million-plus victims, the U.S. government chose to regulate the asbestos family as a whole.

Although the EPA's ban on all forms of asbestos was lifted in 1991, the political and legal climate for asbestos use in the U.S. is still troubled. Few people can recall this mineral's prior glory, and fewer still would ever dream of continuing its widespread use. Past generations may have considered asbestos to be an invaluable resource, but the present concern about its possible risk to human health obscures these memories.

To suggest that asbestos might still hold any redeeming qualities appears foolhardy. To qualify the mineral as a vital commodity of strategic global significance seems completely ridiculous. And yet this is precisely the case. The type of asbestos known as chrysotile (which is softer and less dangerous than the amphiboles), for example, remains an essential mineral for many crucial technologies, with the U.S. government holding military stockpiles to this day.

A prominent demonstration of this lingering importance can be found in the nation's space shuttle program. Each of the ship's solid-fuel boosters carries asbestos-impregnated rubber liners to protect the steel casings from the heat of takeoff. (The use of asbestos in aerospace applications began during the late 19th century, with the efforts to develop a fireproof hot-air balloon. A replica of an early rocket, coated in asbestos to guard against catastrophic structural failure, can be seen today on the main floor of the Smithsonian Institution's Air and Space Museum, openly defiant of the current pressures to remove all asbestos from public areas.)

Asbestos also plays a vital role in the operation of the U.S. Navy's submarine forces. These underwater vessels could not operate without some means of self-contained oxygen production; fibrous mats woven out of asbestos represent a key component in the onboard electrolytic cells that split oxygen from water molecules.

Asbestos can also be found closer to home. At least 75 percent of the chlorine used today for bleach, cleansers and disinfectants comes from chemical industries whose manufacturing processes depend on asbestos products. In fact, the very water we drink might well have been processed with asbestos-treated chlorine as well as piped through an asbestos-cement conduit on its way to our houses. Enough of the asbestos-cement pipe has been used in all 50 states since 1930 to circle the earth eight times over and still run to the moon and back.

A Rational Perspective

Admittedly, all these present-day applications (which rely mainly on the safer chrysotile form) do not require huge amounts of asbestos. Indeed, the consumption of asbestos in the U.S. has fallen by about 95 percent from the 1973 peak. Beyond our country's borders, though, many nations still consider chrysotile asbestos to be an important resource. In 1997 over two million tons of the substance will be processed

1940

Wicked Witch of the West appeared in the 1939 movie *The Wizard of Oz* with a broom made of asbestos.

Postwar construction projects relied heavily on asbestos.

Wartime paraphernalia—including fireproof suits (*left*) and parachute flares—contained asbestos.

Health concerns began to surface in the U.S. during the 1960s, after studies revealed that low levels of asbestos exposure could be more dangerous than previously thought.

1970

Asbestos use reached an all-time high in the U.S. in 1973.

Removal of asbestos (*above*) from schools, houses and public buildings has been ongoing.

1980

The solid-fuel boosters on the space shuttle (*below*) are insulated with asbestos—one of many current applications of the mineral.

1990

throughout the world, mostly blended into asbestos-cement construction products for use in Asian, eastern European and developing countries.

The public's view of asbestos will probably never return to its previous enthusiasm. Hindsight, however, suggests that efforts to eradicate asbestos might have been somewhat misjudged and mishandled. The predicted rates of future mortality caused by both indoor and outdoor exposure to asbestos fiber now appear minuscule when compared with the risks associated with tobacco smoking and drug and alcohol abuse. The widely espoused and emotionally volatile premise that "one fiber can kill" arguably overstepped the bounds of scientific reality, triggering a purge of asbestos from schools and other buildings with dubious benefit in far too many instances.

Hoping to secure a rational perspective on the asbestos controversy, in 1988 the EPA joined Congress and a variety of concerned private institutions in asking a respected nonprofit organization, the Health Effects Institute, for an independent evaluation of the dilemma. The institute's report attempted to educate the public about the fallacies and economic consequences of rampant asbestos removal. In 1991 the American Medical Association published a second report that reached similar conclusions. These two documents emphasized that current contamination is extremely low compared with the unregulated workplace levels that originally gave rise to asbestos-related lung disease.

The global future for asbestos may hinge on supply as much as safety. Just as the ancient Greek asbestos mines eventually hit rock bottom, today's reserves are being depleted. Chemists have long searched for suitable substitutes, but a perfect solution has not yet been found. The original irony of asbestos has thus come full circle, to a present position where a substance so apparently evil could still be considered good, despite its tarnished image—quite fitting for this unquenchable stone.

The Authors

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Further Reading

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