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COVER: ***A London Dustyard*** **by Edwin Buckman. See "The Archeology of Coal Ash," pp. 23–39.**

The Rise and Fall of the Tacoma Arsenic Industry

Lloyd B. Tepper and Jeffrey H. Tepper

Abstract

For some seventy-five years, Tacoma, Washington, was the center of the arsenic industry in the United States. Arsenic, initially a waste product of copper smelting, became an important by-product of the ASARCO Tacoma smelter. Local manufacturers produced arsenic-based insecticides and herbicides and arsenic-treated lumber. The smelter ceased operations in 1985 on economic grounds. Organic alternatives and environmental considerations led to the termination of the production of arsenical insecticides and herbicides. Uses of treated lumber became highly restricted. Terrestrial contamination with arsenic came to be regarded as a serious environmental problem calling for widespread remedial measures. The former ASARCO site is now under development as a mixed-use residential and commercial property.

The history of the arsenic industry in Tacoma, Washington, is an instructive example of a cycle that begins when an industrial waste that initially appears useless becomes valued after new applications are developed. In this case new products acquire a seemingly essential role, especially in American agriculture. As the cycle continues, however, the products are displaced by more suitable alternatives, and materials that previously had been regarded as industrial waste once again become waste, in this case as dangerous and widely disseminated environmental contaminants that require disposal in a hazardous waste landfill.[1]

Arsenic is a by-product of the smelting of non-ferrous ores, principally those of copper. Until the early twentieth century, post-smelting arsenic residues and arsenic in smelter smoke were generally regarded as useless or objectionable. Neighbors downwind of copper smelters often complained that stack gas and smoke particulates, settling on farmland, injured crops and grazing livestock. Related litigation put pressure on smelters to effect costly remedies. Simultaneously, agricultural scientists, building upon a long history of the use of arsenicals to control insects, developed new arsenic compounds determined to be more effective or less toxic to plants. Thus, the dual influences of the need to control stack emissions and the recognition that arsenicals might have potential as salable products created an environment for arsenic-based prosperity in Tacoma.

For most of the twentieth century, until the mid-1980s, Tacoma was the center of the arsenic industry in the United States. The ascendancy of this industry and its demise seventy-five years later reflect the commercial lives of two independent but closely intertwined industrial sectors, both of which were important contributors to the city's economy. One sector was copper smelting, which produced arsenic (as the trioxide, As_2O_3) as a profitable by-product. The other sector consisted of several industries that used arsenic as an essential feedstock in the manufacture of arsenic-containing products. In this article, we review the history of the Tacoma smelter, the production and industrial uses of arsenic, and the factors that led to the demise of both the smelter and the associated arsenic-based industries. The article demonstrates the multiple facets of the economics of waste and byproduct manufacture that should be part of industrial archeologists' assessments of historic resources associated with extractive industries.

Today little evidence remains of the industries that during their heyday were prominent features of the waterfront along Commencement Bay, an arm of Puget Sound. The smelter was located at Point Defi-

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ance, a peninsula at the mouth of the Bay.[2] The manufacturing industries were located about five miles to the east on the Tacoma Tideflats. This end of the bay had previously been dredged and filled (in part with slag from the smelter) to create channels that could allow deep-water access and to elevate the ground level of the industrial sites between the channels (figure 1).

The Rise of the Tacoma Arsenic Industry

The history of arsenic-related industries in the economy of Tacoma is considered here in two periods. The first encompasses the rise of these industries; the second, their subsequent fall. For each of these periods we discuss the history of the smelter itself and the industries dependent upon arsenic as a feedstock.

The Tacoma Smelter

In 1887, the Northern Pacific Railroad completed its route to Tacoma. Significant mining in Washington state at that time suggested the need for a smelter, and the railroad was eager for ore tonnage. Recognizing business opportunities, the Dennis Ryan Syndicate of St. Paul, Minnesota, organized the Tacoma Milling and Smelting Company, which by 1889 was processing the output of local lead mines (figure 2).[3] Ryan invited William Rust, who had experience with the Black Hawk [Colorado] Stamping Mill Company, to become general manager in 1890. Rust subsequently acquired the smelter, which was reorganized in 1899 as the Tacoma Smelting and Refining Company, and built a highly profitable enterprise.

The production of arsenic in the United States was initiated in 1901 at the Puget Sound Reduction Company's lead smelter at Everett, Washington, which two years later was acquired by the American Smelting and Refining Company (ASARCO). Formed in 1899 by Henry H. Rogers and Leonard Lewisohn to be a consortium of non-ferrous smelting operations in the U.S., ASARCO began with eleven smelters and refineries in Denver, El Paso, Helena, Omaha, Pueblo, and elsewhere.[4] The Everett smelter decomposed arsenic compounds in lead, gold, and silver ores during roasting. The volatile arsenious oxide, passing out with the waste gases, was condensed in cooling chambers and flues, where it settled "in beautiful festoons of pure white crystals resembling snow." The accumulated material was periodically harvested and refined by resublimation in a reverberatory furnace to produce the commercial product, arsenic trioxide (As_2O_3).

By 1905 the Tacoma smelter had attracted the attention of the Guggenheim brothers, who in 1901 had purchased a controlling interest in ASARCO. The company's agent, Bernard Baruch, a New York attorney and highly successful speculator, was directed to

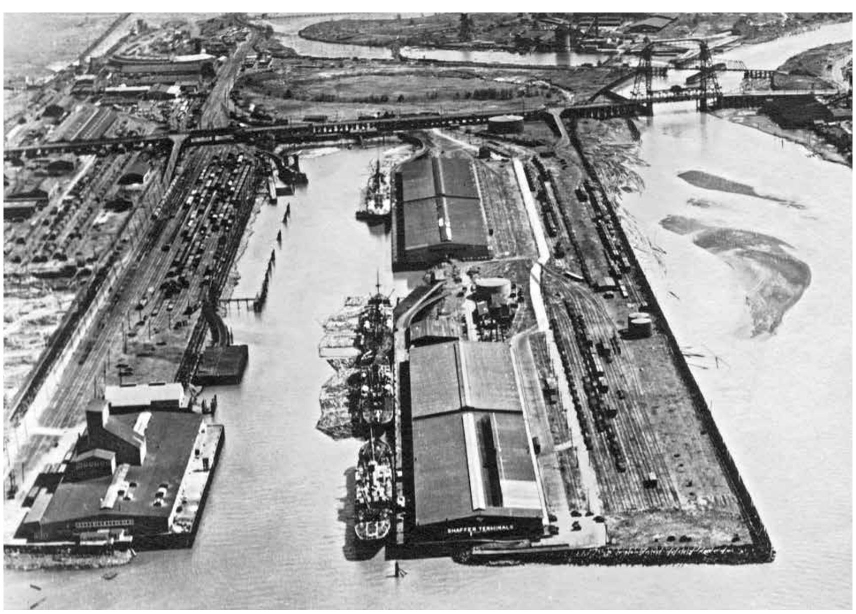


Figure 1. Tacoma Tideflats, ca. 1935. Tacoma Chamber of Commerce postcard, http://earthseaimagery.com/milwaukeeroad.html.

negotiate the purchase of the Tacoma smelter for the American Smelters Security Company, the shares of which were largely in the hands of ASARCO.[5] During the Ryan-Rust period the smelter processed ores containing gold, silver, copper, and primarily lead. However, upon its acquisition by ASARCO, Harry Walker, then manager at Tacoma (and eventually president of ASARCO) and a firm believer in the future of copper, terminated the smelting of lead ores in 1912 and directed the conversion of the smelter to copper production exclusively, processing ores from the Kennecott properties in Alaska, arsenical copper concentrates from Sweden, and ores from British Columbia, Korea, Japan, and South America. The five Guggenheim brothers were widely recognized as "The Kings of Copper."[6]

During the second decade of the twentieth century, ASARCO concentrated its arsenic recovery operations at its Tacoma and Denver works, processing dust from flues, baghouses, and Cottrell electrostatic precipitators, and speiss (a mixture of arsenic compounds produced during smelting) and high-arsenic residues from other non-ferrous smelters.[7] ASARCO had made a specialty of by-product recovery. Material that previously had been regarded as a nuisance, dumped on the ground or allowed to fall from smelter smoke discharged into the atmosphere, was acquiring important commercial value. Copper ores with high arsenic content, typically 3–11 percent, became desirable to ASARCO.[8]

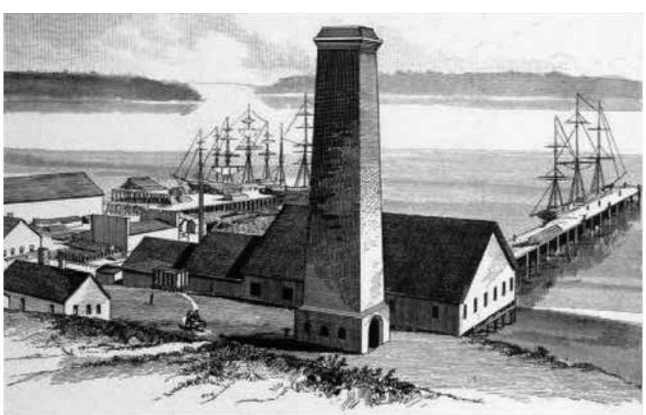


Figure 2. "The Great Ryan Smelter," 1889. Image from *Tacoma Illustrated* (see n. 3). Note ships bringing ore from Alaska and as ballast in South American lumber vessels.

An additional factor contributing to the recovery of arsenic from roaster gas was the impetus to reduce litigation related to allegations of harm to crops and livestock attributed to smelter stack emissions of arsenic and sulfur dioxide. Smelter discharges were thought to have affected residents in Manchester, England, in 1900. In 1905 in Montana, the Anaconda Copper Mining Company (ACM) acknowledged that arsenic deposited on downwind farmland was killing livestock. The company paid damages to farmers and closed the smelter to rebuild the flue and stack system. Later, farmers citing further credible evidence of livestock arsenic poisoning sought to enjoin the smelter from operating; the ACM vigorously resisted. It won the suit brought by the farmers, but not for lack of evidence of arsenical poisoning. Rather, the judge ruled that closing the smelter would mean closing the mines, and that would do greater harm to the farmers by loss of their principal markets, cities dependent on mining and smelting.[9]

Legal battles with injunctions affecting production had already become a serious problem for ASARCO, especially at the Selby works in California, where the lead smelter had been enjoined in 1912 from operating during the summer months, when prevailing winds carried the smoke plume over farmlands. The first lawsuit in Tacoma was not filed until 1917, when failure of fruit trees and berry crops was attributed to smelter smoke. The company no doubt had anticipated adverse Tacoma community reaction to smoke, for in 1916 it installed a Cottrell precipitator system, and two years later the Alphons Custodis Chimney Construction Company of New York completed a 573-ft. smokestack, the tallest in the world at the time.[10]

Driven largely by expanding agricultural applications ("due to the vigorous spraying propaganda of various agricultural bureaus and colleges"[11]) and for a short period by the manufacture of chemical warfare agents, arsenic production at the Tacoma works increased through the ensuing years, peaking in the 1940s and 1950s, decreasing thereafter until its closure in 1985. From the mid-1970s until its closure, the Tacoma ASARCO smelter was the only domestic producer of arsenic, with an output of about 10-18 thousand tons a year of arsenic trioxide (figure 3).[12] Throughout its ninety-six-year history the smelter was a major Tacoma employer. The principal product of the smelter, however, was always copper, but arsenic as a byproduct was a vital feedstock for three local industries.

The Arsenic-Using Industries

Insecticides

Of the Tacoma arsenic-using industries, the leading one was engaged in the production of arsenical insecticides, which had a long history. Paris green (copper acetoarsenite) was initially used as a rodenticide to control the rat population in the sewers of Paris. In1867 it was used on the Colorado potato beetle, and later on the canker worm and the codling moth.[13] The less phytotoxic and more persistent lead arsenate came along in 1891, primarily for the control of the gypsy moth and later for the codling moth and boll weevil (figures 4 and 5). By 1912 both lead and calcium arsenates were on the commercial market for multiple insecticidal applications, and by 1944, the peak year, eighty-six million pounds of lead arsenate and as much as forty-two million pounds of calcium arsenate were being applied to crops annually for insect control (figure 6).[14] Additionally, lead arsenate was widely adopted in citrus-growing areas as a growth regulator to accelerate the maturity of grapefruit and increase the sugar/acid ratio. Treatment of a portion of the crop could lengthen the marketing season by one or two months.[15] Fruit that would otherwise not reach market maturity until November would be ripe in September or October.

Taking advantage of the arsenic production at the Tacoma smelter, Latimer-Goodwin, a Colorado manufacturer of insecticides, established an insecticide plant on the Tideflats in 1925. It became the largest of its kind in the world, with an initial output of about five tons a day of lead and calcium arsenates (figure 7).[16]

Figure 3. ASARCO Tacoma smelter. *Left:* Custodis stack, 573 ft. high, the tallest stack in the world at the time of its construction. Photo from the collection of Karen Pickett, Ruston Home blog.

Figure 4. Codling moth (*left*) and typical larval damage to fruit (*right*). Photo of moth by Olaf Leillinger. Photo of fruit from Jim Conrad's Naturalist Newsletter, 13 September 2009.

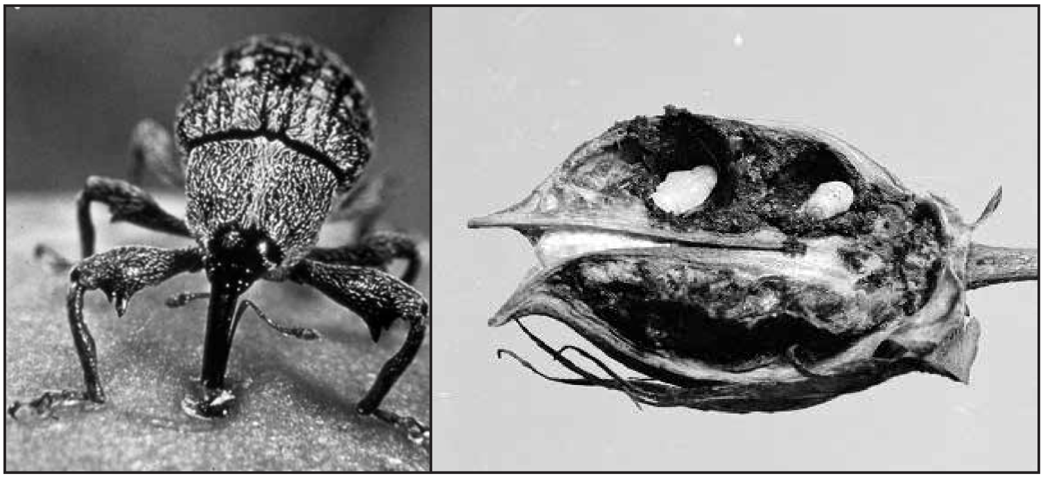
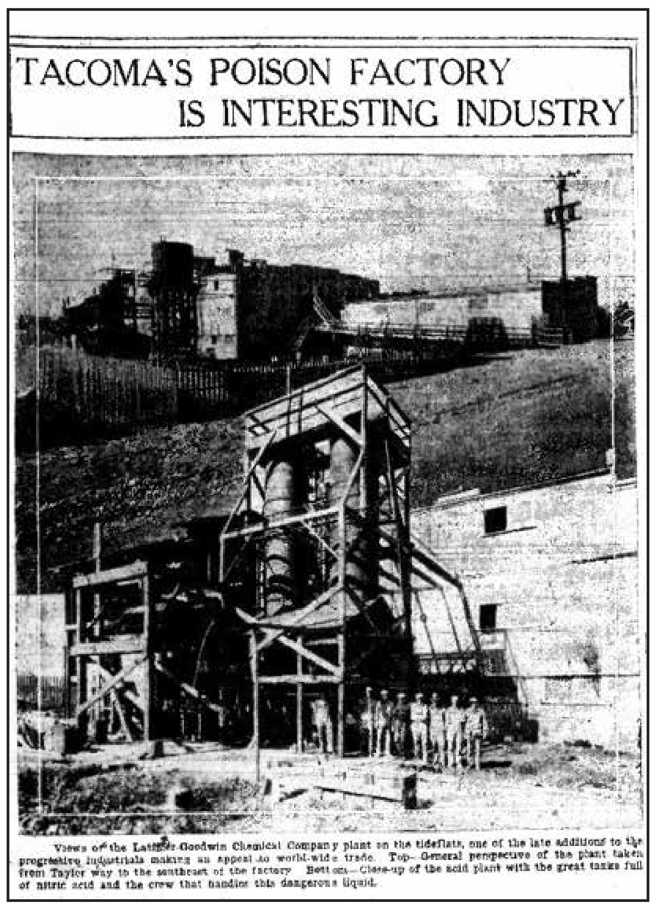


Figure 5. Boll weevil (*left*) with typical damage to cotton boll (*right*). Image (*left*) from the collection of Mississippi Agriculture and Forest Experiment Station, Mississippi State University, ttp://msucares.com/news/print/agnews/an08/081030.html; (*right*) photo collection of Clemson University USDA Cooperative Extension, Clemson, South Carolina.

Figure 6. Application of calcium arsenate dust to cotton plants, Tallulah, LA, ca. 1935. Note absence of personal protective equipment of any sort and the potential for harmful arsenic absorption. Photo, Records of the U.S. Department of Agriculture, National Archives.



TACOMA'S POISON FACTORY IS INTERESTING INDUSTRY

Views of the Latimer-Goodwin Chemical Company plant on the tideflats, one of the late additions to the progressive industrials making an appeal to world-wide trade. Top—General perspective of the plant taken from Taylor way to the southeast of the factory. Bottom—Close-up of the acid plant with the great tanks full of nitric acid and the crew that handles this dangerous liquid.

Figure 7. Booming Tacoma industry. *The Tacoma* (WA) *News Tribune*, 6 April 1927, p. 13.

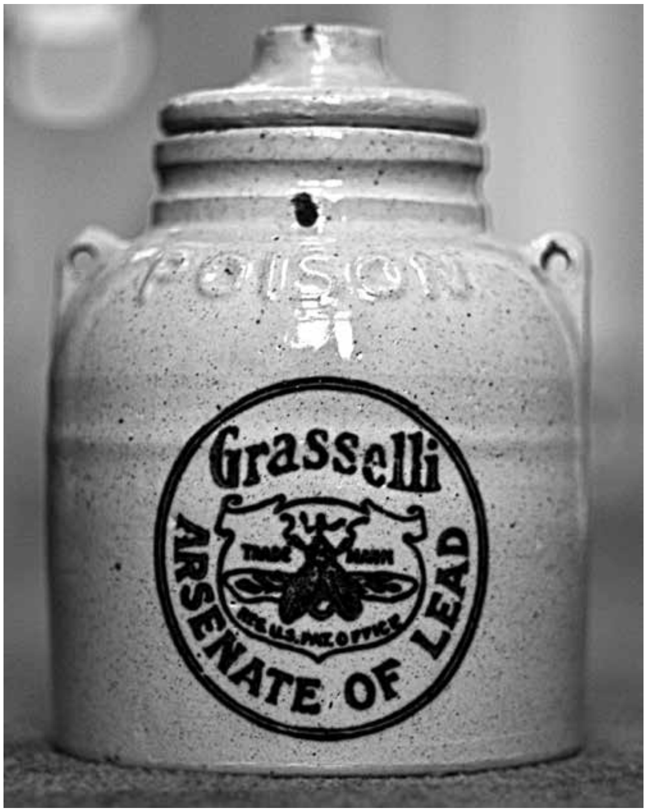


Figure 8. Grasselli insecticide crock, 2011. Photo by Whitney A. Weaver, Virginia Tech Pesticide Programs, Virginia Polytechnic Institute, Blacksburg, VA.

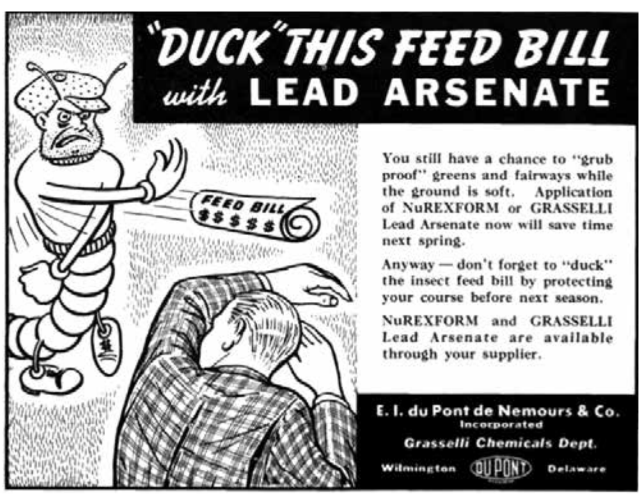


Figure 9. DuPont's Grasselli Department's sales promotion. *Golfdom* magazine, October 1939, 6.

By 1927 the plant was shipping thirty-five carloads a month with additional allocations going by ship to the eastern US market. In 1944, the Grasselli Chemicals Department of E. I. du Pont de Nemours and Company purchased the plant and continued to produce lead and calcium arsenates until 1946 (figures 8 and 9).[17] The plant also conducted insecticidal dust mixing and warehouse operations until closure in1949.[18]

Herbicides

Sodium arsenite ($NaAsO_2$), the reaction product of arsenic trioxide and sodium hydroxide, first found use about 1890 as a non-selective weed killer and soil sterilant, and was for many years applied to railroad rights of way, freight yards, and industrial sites.[19] The compound was also used as a tick-killing livestock dip, as a fungicide for grapes, and to control early and late blight in tomatoes, although it was very phytotoxic and required careful application. Commencing in 1955, arsenic acid (H_3AsO_4) was used as a desiccant on "stripper" cotton, the low, shrubby crop raised in the unirrigated, low-rainfall areas of Texas and southwestern Oklahoma.[20] The intent was to deplete the leaves and stems of moisture prior to cotton harvest so as to facilitate the removal of plant refuse in the lint-cleaning process and to reduce green staining.

In Tacoma, sodium arsenite was produced from 1940 to 1971 by the Tacoma Electrochemical Company, which was later renamed Pennsalt. Pennsalt was founded as the Pennsylvania Salt Company in 1850 by a group of Philadelphia Quakers and began its Tacoma operations in 1929, producing caustic soda and chlorine for the local paper makers (figure 10).[21] From 1940 to 1971 the Tacoma plant also produced the weed killer sodium arsenite, marketed under the trade name Penite, purchasing its arsenic trioxide from ASARCO for reaction with internally-produced sodium hydroxide.[22] Pennsalt also provided arsenic to its sister plant in Texas, which manufactured arsenic acid as a desiccant for the regional cotton industry.

Wood Preservation

The most enduring major use of arsenic has been in the preservation of wood with chromated copper arsenate (CCA), the invention of Sonti Kamesam, a scientist at the Forest Research Institute at Dehra Dun, India.[23] He had been a student of Karl Heinrich Wolman in Germany, the inventor of Wolman salts and Wolmanized lumber.[24] Kamesam's fundamental contri-

Figure10. The Pennsalt Tacoma works, 1949. Photo A41825-3, Richardson Collection. Courtesy of the Tacoma Public Library, Tacoma, WA.

bution, in 1933, was to combine copper as a fungicide, arsenic as an insecticide, and chromium as a fixative, so that the preservative mix resisted leaching and remained bound in the wood.[25] He patented the process in the United States in 1938 and sold it to the Bell Telephone Company for reliable pole preservation.

Preserving wood with CCA is straightforward: at the treatment plant, wood is loaded onto a tram running on rails and carried into a pressure cylinder or "retort," a term common in the industry, which is then sealed (figure 11). A vacuum is applied to remove air from the chamber and the wood cells. The vessel is then flooded with preservative solution under pressure (150–250 psi) to "the point of refusal," when no additional preservative is accepted. Finally, the vessel is emptied of treatment liquid, and a vacuum is reapplied to remove unabsorbed preservative and to reduce dripping.

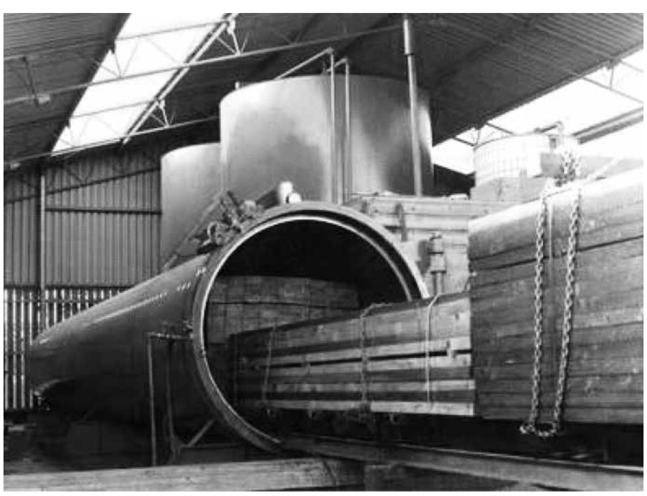


Figure 11. Retort for pressure treatment of lumber. Photo courtesy of IWT Moldrup Llc., Vejle, Denmark.

Terrestrial applications of CCA include the rot-proofing of utility poles, railroad ties, and ground-contact building components. CCA impregnation for aquatic uses includes the treatment of poles, posts, and bulkhead timbers. Several wood treatment companies existed in Tacoma over the years, and wood treatment products based on ASARCO Tacoma arsenic were used throughout the United States. Green-tinged CCA-treated wood was not an especially popular or profitable product; however, in 1974 the Koppers Company, after testing the market in Chicago, launched a program promoting residential decks.[26] Sales accelerated dramatically as the concept of a rot-proof rustic deck gained wide appeal, and Americans entered the "Age of the Deck." Annual sales for CCA-treated lumber grew as much as 40 percent per year in the late 1970s. By 2000 the annual utilization of CCA, expressed as the mixed metal oxides, was 70,000-85,000 tons. In Tacoma, McFarland-Cascade Pole and Lumber, which had its origin as a pole creosoting operation in Idaho in 1916, added CCA preservation in the 1970s (figure 12).[27] Since then the company has manufactured a variety of CCA-treated wood products, although these have become less important as they can now be used only for restricted applications.[28]

Other Uses of Arsenic

Arsenic trioxide from Tacoma was sold nationally for a variety of applications.[29] In addition to the three principal arsenic-using industries described above, there were several others that used arsenic as a feedstock. Of these the most important in terms of arsenic use was glass manufacturing, which used arsenic trioxide as a fining agent to eliminate bubbles and the greenish color of glass due to iron.[30] Today this application is essentially obsolete and rarely used.

Arsenic has also been used in pharmaceuticals, the most notable one being arsphenamine (Salvarsan), the first modern chemotherapeutic agent, which was developed by 1908 Nobel laureate Paul Ehrlich and his colleague Sahachiro Hata for the treatment of syphilis.[31] Their "magic bullet" represented the culmination of an extended search for a drug that would be effective and yet have acceptable side effects, and it was the standard treatment for syphilis until penicillin rendered it obsolete in 1943. Minor arsenical drugs for human use remain and include arsenic trioxide (Trisenox®) for the treatment of acute promyelocytic leukemia and melarsoprol (melarsen, Arsobal®) for African sleeping sickness, trypanosomiasis.

Coccidiosis is a devastating parasitic disease that occurs in commercial flocks of chickens and turkeys.[32] Growth of the parasite can be inhibited by the addition of an arsenical coccidiostat, such as roxarsone (3-Nitro®, Ren-O-Sal®), to the feed. However, the recent finding of potentially carcinogenic inorganic arsenic in the meat of chickens raised on roxarsone-containing feed led to the voluntary suspension of sales by the principal American manufacturer. Arsanilic acid found use as a minor amendment to swine feed, the compound promoting weight gain and feed efficiency. Histostat® (nitarsone) is approved for the prevention of histomoniasis (blackhead disease), which occurs seasonally and regionally in turkeys and causes significant mortality.

The use of arsenic in alloys is not common today, the exception being in the manufacture of shot. Arsenic hardens lead and is said to make shot more spherical when it is manufactured by the old shot-tower method. Arsenic also raises the annealing temperature of copper, so that a work-toughened alloy is more resistant to softening by heat. This was an important consideration in the fabrication of copper locomotive fireboxes, long used by the British, who distrusted steel for this application.

Gallium arsenide semiconductors were first produced commercially in 1960, and the market for this compound and for arsine gas (hydrogen arsenide), a dopant, has grown steadily in the production of microwave devices, lasers, LEDs, and semiconductors. But how-

Figure 12. McFarland-Cascade Tacoma site, 1947. Photo D28551-1, Richardson Collection. Courtesy of the Tacoma Public Library, Tacoma, WA.

ever vigorous this industry may be, the demand for feedstock arsenic is small, and the profit is in refining these compounds to 99.9999 percent purity, an activity not conducted in the smelting industry.[33]

The Fall of the Tacoma Arsenic Industry

Two main factors contributed to the fall of the Tacoma arsenic industry: the dramatic scientific and technological achievements of the organic chemical industry following World War II and a rising national (and international) awareness of factors affecting the ambient environment. The publication in 1962 of Rachel Carson's *Silent Spring* mobilized a small and marginally effective environmental movement into a major cultural, political, and economic force.[34] It is ironic that, although she was highly critical of arsenical pesticides and applauded their decline, Carson's principal focus and condemnation was directed toward their replacements, especially DDT and other chlorinated hydrocarbons.

The Smelter

The demise of the Tacoma smelter occurred against a backdrop of growing awareness of the detrimental effect of environmental pollutants resulting from industrial production, in this case sulfur dioxide and arsenic. The "aroma of Tacoma" had been famous for years, but in the 1980s the arsenic emissions, 25 percent of all inorganic arsenic emissions nationwide, were becoming a central social, economic, and regulatory issue. Arsenic had been recognized as a probable human carcinogen since 1820, when J. Ayrton Paris described cancer of the scrotum among copper smelter workers.[35] However, the publication of epidemiological studies starting in 1977, showing an elevated risk of lung cancer specific to Tacoma smeltermen, converted a somewhat distant and unfocused understanding of the risk into an immediate and more personal threat. A time-weighted index of total lifetime exposure at the smelter was linearly related to risks of respiratory cancer as high as eight times that expected. Statistical calculations suggested that arsenic at the workplace caused an annual excess of four lung cancer deaths at the ASARCO smelter above the rate expected for non-exposed men. It was also reasonable to assume that arsenic emissions were having negative health effects in the surrounding community.[36]

During the 1970s ASARCO had invested $40 million to reduce its arsenic emissions, yet new court rulings in 1983 mandated an additional 25 percent reduction. This was the level calculated to reduce the number of excess cases of lung cancer per year from four to one. ASARCO indicated its willingness to make the investment, but then the Environmental Protection Agency (EPA) announced that the smelter might be required to reduce its arsenic emissions to zero so as to reduce the attributable cancer risk to zero.[37] Eliminating all arsenic emissions would have required smelter modifications that could not be justified economically.

In 1983, William Ruckelshaus, EPA Administrator under Presidents Nixon and Reagan, made a bold and innovative proposal of "participatory democracy," involving the community in the regulatory decision.[38] Was Tacoma willing to accept one additional case of lung cancer each year, or would it chose to eliminate that risk, along with the employment of 600 people at the smelter and 500 in the community, $2 million in tax revenues, and $20 million annual contributions to the local economy? Said Ruckelshaus: "For me to sit here in Washington and tell the people of Tacoma what is an acceptable risk would be at best arrogant and at worst inexcusable."[39] The community had to confront scientific uncertainty and a difficult choice. Vigorous debate and strongly opposing views characterized the three EPA workshops and several others sponsored by independent groups, such as the United Steelworkers.

Before the "Tacoma process" could yield a decision, meetings and debate over arsenic regulation became moot. The ASARCO Tacoma smelter was the only domestic producer of arsenic from the 1970s through 1985, and the domestic demand for arsenic still exceeded its output at the time of its demise in 1985. However, ASARCO's problem lay in the fact that arsenic was a by-product of non-ferrous metal smelting: the Tacoma plant was operated to produce copper, not arsenic. Thus, whether or not arsenic was produced was linked to the output of copper, and in 1985 the price of copper was very low (figure 13). In addition, even as the EPA arsenic standard was being debated, further controls on sulfur dioxide and in-plant worker exposures to toxic materials were on the horizon.[40] So although the demand for arsenic was still strong, overriding commercial considerations led to the termination of smelting in Tacoma in 1985. The arsenic plant remained in operation until the following year to process remaining inventories.

ASARCO filed for Chapter 11 bankruptcy in 2005 and, after a four-year legal battle, paid the EPA and other agencies $1.79 billion to settle claims for environmental pollution in nineteen states.[41] Of this amount, some $90 million was directed to the Tacoma site. ASARCO had become a subsidiary of Grupo Mexico in 1999, but amid the bankruptcy, a workers' strike, and over $1 billion in environmental and asbestos claims, a federal judge overseeing the bankruptcy process removed Grupo Mexico from control of ASARCO, replacing it with a board of creditors including the United Steelworkers. ASARCO returned to the Grupo Mexico family of companies in 2009, emerging from its restructuring as a much diminished but financially viable organization.

Insecticides

Loss of arsenic supply notwithstanding, there were several other causes for decline in Tacoma's arsenic-using industries. The first was related to innovations in organic chemistry. The insecticidal properties of DDT were discovered in 1939 by Nobel laureate Paul Müller, and by 1943 the compound was recognized as an effective replacement for arsenical insecticides. DDT showed an impressive capacity to prevent a widespread louse-borne typhus epidemic in Europe following the devastation of World War II. Additionally, cholinesterase-inhibiting insecticides (e.g., parathion, malathion, and congeners) evolved from the German chemical warfare agents tabun and sarin, developed by Gerhardt Schrader of I. G. Farbenindustrie. These new insecticides were effective at low dosages per acre and left no toxic residues in soil, a clear advantage over the arsenicals. Lead and calcium arsenate pesticides lost commercial importance in the 1970s and were banned in 1988.[42] Organic growth regulators as harvest aids in grapefruit production supplanted lead arsenate in 1988, as the replacements were functionally satisfactory. Furthermore, the public had grown increasingly concerned over toxic residues on fruit.

The once-thriving Latimer-Goodwin/DuPont plant in Tacoma essentially terminated its operations in 1949, and by 1951 the property was sold to a lumber company and the City of Tacoma. The site is now occupied by the Superlon Company, a manufacturer of extruded high-performance polyethylene pipe. The company and Washington state have collaborated in remediation of the site to control arsenic residues from former insecticide production and from the use of slag from the smelter as landfill.[43]

Herbicides

Organic chemistry also led to development of new herbicides and defoliants, including 2,4-D, 2,4,5-T, and glyphosate (Roundup®). It had become increasingly evident that arsenate and arsenite residues in soil caused leaf drop in stone fruits. In addition, soil residues of arsenic in cotton fields converted to growing rice contributed to "straighthead disease," reducing yield. Furthermore, while sodium arsenite had been effective in controlling aquatic weeds—and fish were generally tolerant of the treatment—livestock and wild animals drinking the contaminated water were being poisoned. Ponds treated with sodium arsenite could not be used for potable water or swimming. EPA regis-

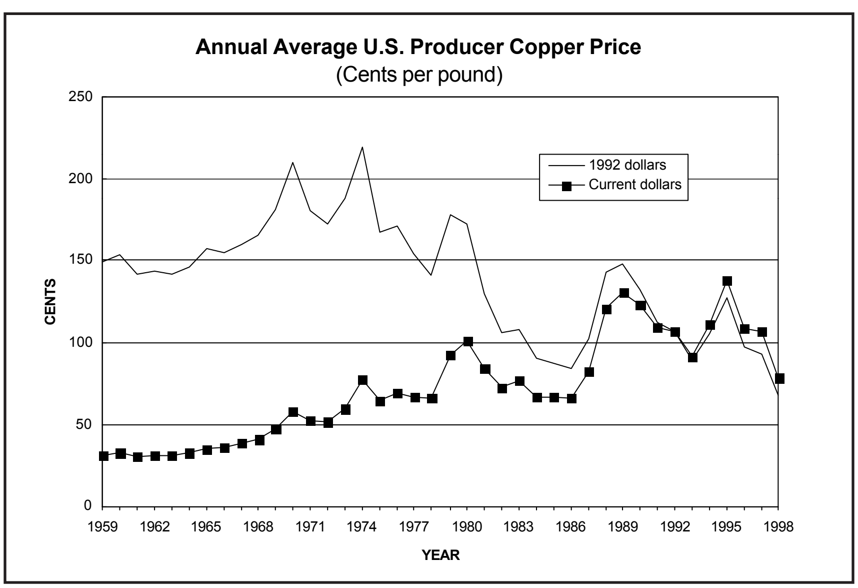


Figure 13. Copper Prices 1959–1998. Graph from Daniel Edelstein, "Copper," USGS, ca. 1999, http://minerals.usgs.gov/minerals/pubs/commodity/copper/240798.pdf

trations of all inorganic arsenical herbicides and defoliant/desiccants were cancelled by 1988; registration of sodium arsenite as a fungicide for grapes was cancelled in 1992.[44]

Registration of the only remaining organic arsenical, MSMA (monosodium methylarsenate, monosodium methanearsenate) was cancelled in 2009 for use on residential lawns, park lawns, and athletic fields. It is currently registered as a broad-spectrum, post-emergent herbicide for cotton and for turf grasses on golf courses, sod farms, and highway rights-of-way. Final determination of the continued registration for these applications is under review and is expected to be completed by 2019.[45]

Pennwalt's production in Tacoma of the herbicide sodium arsenite ceased in 1971. The manufacture of other products terminated in 1997, and most of the buildings were demolished. Groundwater had become seriously contaminated, in large measure, as a result of waste material (reaction sludge, washdown water, and filter cake) having been deposited in a number of on-site pits. The Port of Tacoma bought the property in 2007, and remediation is underway but will take years to complete. There is an Agreed Order with the state Department of Ecology's Toxic Cleanup Program.[46] No structures currently exist on the site, and the Port of Tacoma has not indicated its intended disposition.

Wood Preservation

Early in this century, 99 percent of all treated lumber and plywood in the U.S. was impregnated with CCA, and 150 wood treatment plants in the nation handled 100 million cubic feet of wood annually. However, environmental considerations and public pressure induced the wood preserving industry to voluntarily terminate the use of CCA for so-called "consumer uses" (e.g., decks, playground equipment, picnic tables) in December 2003, and the EPA approved the modified registrations.[47] The long-familiar "green lumber" at building supply stores disappeared. Replacements for CCA, such as ACQ (alkaline copper quaternary), are not as effective as CCA for severe ground contact uses, and CCA is still available for industrial and marine applications such as utility poles, railroad ties, pilings, bulkheads, and non-residential docks.

Animal Husbandry

In February 2014, Zoetis, owner of the veterinary drug roxarsone (3-Nitro®), voluntarily withdrew all approvals for the coccidiostat and for arsanilic acid, used in animal feeds. In April 2015, the company announced that, by the fall 2015, it would cease marketing Histostat® (nitarsone), the only remaining arsenic-based animal drug on the market, and it will not be available for the 2016 growing season.[48]

Tacoma and Arsenic Today

Most of the buildings at the ASARCO site were removed in the late 1980s, the smokestack was demolished in 1993, and the contaminated soil and debris were subsequently buried in situ beneath an impermeable concrete cap. Today the property is home to Point Ruston, a $1.2 billion development that includes condominiums, restaurants, a movie theater, and a waterfront promenade (figure 14).[49] The fifteen-million-ton

Figure 14 Point Ruston Development, July 2015. Compare with Figure 3. Photo by J. H. Tepper.

ASARCO slag pile, which forms a twenty-three-acre peninsula extending into Commencement Bay, is now the site of the Tacoma Yacht Club and is scheduled to be capped with clean soil in the near future (figure 15). The only remaining arsenic-using industry in Tacoma is the CCA wood preservation operation of McFarland-Cascade, and that is substantially scaled down in comparison to its status prior to 2003.

The history of Tacoma's arsenic industry demonstrates that the worth of substances such as arsenic can undergo substantial changes in the eyes of those who assess their value. At one time considered a useless but toxic waste of the smelting industry, arsenic made a transition to valuable byproduct as enterprising chemists and agricultural scientists developed marketable uses for the element. Based on those markets, derivative industries grew in Tacoma, predicated on the smelter's abundance of waste arsenic. But as understanding of arsenic's environmental impacts evolved, and as markets for pesticide, herbicides, and preservatives responded to that understanding, demand for arsenic declined. This corresponded, roughly, with the decline in Tacoma's smelting industry.

Evironmental remediation is the principal arsenic-related activity in Tacoma today. While it is doubtful that Tacoma's citizens would want to see the reestablishment of arsenic-based industry in their community, there is no question that this toxic element, at one time considered a useless waste, contributed significantly to the prosperity and industrial history of the city.

Figure 15. Tacoma Yacht Club. Photo courtesy of Marinas.com, http://marinas.com/search/?search=1&category=marina&q=Tacoma+Yacht+Club.

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Notes

1. Portions of this article were presented at the annual conference of the Society for Industrial Archeology, Seattle, WA, 4 June 2011.
2. The "Tacoma" smelter was actually located in Ruston, a 0.3-sq. mi. incorporated community first named "Smelter," a company town. However, in 1906 the residents voted to change the name in honor of William Rust, the principal figure in the smelter's early history. Most references and this article designate the location of the smelter as Tacoma, which surrounds Ruston on three sides, the fourth side being Commencement Bay.
3. *Tacoma Illustrated; Published under the auspices of the Tacoma Chamber of Commerce. A careful compilation of the resources, terminal advantages, institutions, climate, business & manufacturing industries of the "City of Destiny"* (Chicago: Baldwin, Calcutt, and Co. 1889), 17; Isaac F. Marcosson, *Metal Magic: The Story of the American Smelting & Refining Company* (New York: Farrar, Straus, and Co., 1949), 141; William Farrand Prosser, *A History of the Puget Sound Country: Its Resources, Its Commerce, Its People: With Some Reference to Discoveries and Exploration of North America from the Time of Christopher Columbus to that of George Vancouver in 1792* (Chicago: The Lewis Publishing Co., 1903), 332.
4. Joseph Struthers, "Arsenic," *Mineral Resources of the United States, 1903* (Washington: Government Printing Office, 1904), 327; Marcosson, *Metal Magic*, 60–64, 79 (see n. 3).
5. Marcosson, *Magic Metal*, 77–82 (see n. 3). Bernard M. Baruch (1870–1965), a highly successful Wall Street speculator and financier, received a $1 million commission for negotiating the Tacoma (and Selby, CA) smelter acquisitions. He became a respected advisor to American presidents for over forty years. See "Smelters Branch Votes to Dissolve," *New York Times*, 15 December 1922, 35. The American Smelters Securities Company was organized in 1905 in an arrangement whereby the company acquired for ASARCO the control of important mines and the Tacoma smelter. ASARCO gradually increased its holdings of the Securities Company, and in 1922 held all but 11 percent of the outstanding shares, at which time the Securities Company was dissolved.
6. "Editorial," *Engineering and Mining Journal*, 79, no. 14 (1905): 666 (hereafter *E&MJ*).
7. V. C. Heikes and G. F. Loughlin, "Arsenic," *Mineral Resources of the United States, 1923* (Washington: Government Printing Office, 1927), 161.
8. L. D. Fitzgerald, "Arsenic Sources, Production and Applications in the 1980s," in *Arsenic: Its Industrial, Biomedical, Environmental Perspectives*, eds. William H. Lederer and Robert J. Fensterheim (New York: Van Nostrand Reinhold Co., 1983).
9. W. D. Harkins and R. E. Swain, "The Chronic Arsenical Poisoning of Herbivorous Animals," *Journal of the American Chemical Society*, 30 (June 1908): 928–946; Charles H. Fulton, *Metallurgical Smoke*, United States Bureau of Mines Bulletin 84 (Washington: Government Printing Office, 1915): 86, digital.library.unt.edu/

ark:/67531/metadc12296/; "Bureau of Mines Reports Progress in Smelting Investigation," *E&MJ* 105, no. 6 (1918): 283; Fredric L. Quivik, "The Tragic Montana Career of Dr. D. E. Salmon," *Montana: Magazine of Western History* 57, no. 1 (2007): 39–43. Salmon is best known for his research on the bacterial genus *Salmonella*, after whom it is named. Gordon Morris Bakken, "Was There Arsenic in the Air? Anaconda versus the Farmers of Deer Lodge Valley," *Montana: Magazine of Western History* 41, no. 3 (1991): 32–35, 41. See also Donald MacMillan, *Smoke Wars: Anaconda Copper, Montana Air Pollution, and the Courts, 1890–1920* (Helena: Montana Historical Society Press, 2000).

10. "Copper Smelter Conditions in the Pacific Northwest," *E&MJ* 102, no. 7 (1916): 298; "The Mining News—Washington," *E&MJ* 103, no. 3 (1917): 168; "Tall Chimneys in Metallurgical Plants," *E&MJ* 106, no. 4 (1918): 16; "Charges Smelter Smoke Damaged Garden and Fruit," *Tacoma* (WA) *Tribune*, 24 October 1917, p. 8; People v. Selby Smelting & Lead Company, California Supreme Court, 163 Cal. 84 (June 12, 1912), in *Pacific Reporter*, vol. 124 (St. Paul: West Publishing Co., 1912), 692–697.
11. "Arsenic in 1911," *E&MJ* 93, no. 1 (1912): 83.
12. M. O. Varner to Dr. Sam Milham, letter dated 1984, cited in Gregory L. Glass (consultant), "Tacoma Smelter Plume Site Credible Evidence Report: The ASARCO Tacoma Smelter and Regional Soil Contamination in Puget Sound," report to Tacoma-Pierce County Health Dept. and Washington State Dept. of Ecology, September 2003, p. 25, https://fortress.wa.gov/ecy/gsp/DocViewer.ashx?did=5786. Varner was Director, Department of Environmental Sciences, ASARCO, Salt Lake City, Utah. Milham was with the Washington State Department of Social and Health Services. The letter includes production data for As_2O_3 by the ASARCO Tacoma Smelter 1931–1960. The annual production of arsenic trioxide by ASARCO Tacoma was in the range of 12,000–18,000 tons. (The arsenic production cited in Marcosson's *Metal Magic*, p. 142, is 50,000 tons/year. This is implausible and is inconsistent with other production reports.) Production reported by the U.S. Bureau of Mines in annual editions of *Mineral Resources of the United States* and *Minerals Yearbook* varied, but during the period 1960–1985, the average was approximately 13,000 tons.
13. National Research Council (US) Committee on Medical and Biological Effects of Environmental Pollutants, *Arsenic: Medical and Biological Effects of Environmental Pollutants* (Washington: National Academies Press, 1977); copper acetoarsenite, also known as Paris green, emerald green, and Schweinfurt green, was an important green pigment used in oil paintings, wallpaper, soap, and even cake decorations and confectionary. Its "secret" composition was published by the German chemist Liebig in 1822, and its toxic properties soon became apparent.
14. E. A. Murphy and M. Aucott, "An Assessment of the Amount of Arsenical Pesticides Used Historically in a Geographical Area," *Science of the Total Environment* 218, no. 2 (1988): 89–101.
15. W. C. Wilson, "Methods for Controlling Acidity of Citrus," *Proceedings of the Florida State Horticultural Society* 101 (1988): 157–161.
16. "Tacoma's Poison Factory is Interesting Industry," *The Tacoma* (WA) *News Tribune*, 6 April 1927, p. 13.
17. "DuPont Acquires Tacoma Latimer-Goodwin for Grasselli Chemicals Department," *Industrial and Engineering Chemistry* 36, no. 5 (1944): 484; "History of Grasselli Chemical Exploits in the US," www.atkeson.net/history/grasselli. The Grasselli Chemical Company had its origins in Italy during the fifteenth century and initiated its American operations in 1839. In 1928, the company, then the world's largest producer of lead arsenate, was acquired by E. I. du Pont as its Grasselli Chemicals Department. In 1959, Grasselli Chemicals was reorganized as DuPont's Industrial and Biochemicals Department; Peter Jentsch, http://web.entomology.cornell.edu/jentsch/assets/historical-perspectives-on-apple-production.pdf.
18. "Interim Action Work Plan for the Superlon Plastics Site, Tacoma, Washington," prepared by Jeffrey D. King, Pacific Environmental and Development Corp., Snohomish, WA, for White Birch and E. I. duPont de Nemours and Co., January 2, 2010, https://fortress.wa.gov/ecy/gsp/DocViewer.ashx?did=2697.
19. William R. Cullen, *Is Arsenic an Aphrodisiac? The Sociochemistry of an Element* (Cambridge, UK: The Royal Society of Chemistry, 2008). This book is a comprehensive and not-too-complex overview of the uses, hazards, and popular reports and anecdotes concerning arsenic. The title is somewhat misleading, and the answer to the question is no.
20. J. R. Abernathy, "Role of Arsenical Chemicals in Agriculture," in *Arsenic* (see n. 8); L. M. Stahler, "Contact Herbicides As Preharvest Defoliants and Desiccants," *Journal of Agriculture and Food Chemistry* 1, no. 2 (1953): 183–187; Stephen H. Crawford, J. Tom Cothren, Donna E. Sohan, and James R. Supak, "A Hisory of Cotton Harvest Aids," in eds. J. R. Supak and C. E. Snipes, *Cotton Harvest Management: Use and Influence of Harvest Aids* (Memphis: The Cotton Foundation, 2001); Robert L. Nichols, agronomist and senior director, Cotton Inc., telephone conversation with L. B. Tepper, June 22, 2011.
21. "American Chemical Industries—Pennsylvania Salt Company," *Industrial Engineering Chemistry* 20, no. 7 (1928): 775–776; Pennsalt Tacoma Works, Image Archives, Richardson Collection, A100512, Tacoma Public Library, Tacoma, WA. Pennsalt changed its name many times as a result of mergers and acquisitions. It became Pennwalt in 1969, Atochem North America in 1989, Elf Atochem in 1992, Atofina Chemicals in 2000, and Arkema in 2004. It is ironic that the Pennsylvania Salt Company unsuccessfully sued Meyer Guggenheim, family patriarch and father of the five "Copper King" brothers, for patent infringement in the 1880s.
22. Frederick Wolf, "Groundwater Site Characterization: A Systemic Perspective," *Journal of Environmental Health* 56, no. 7 (1994): 13–18.
23. Sonti Kamesam, Wood Preservative Composition, US Patent 2,106,978, issued February 1, 1938.
24. In 1907 in Austria Dr. Karl Heinrich Wolman patented a preservative for mine timbers consisting of sodium and potassium fluorides and six years later added dinitrophenol to the product. Wolman salts marketed over the years under such names as Triolith and Tanalith, have varied in composition to include chromate, borates, dinitrocresol, and in 1922, sodium arsenate as an insecticide. The trade names Wolman® and Wolmanized® are currently owned by BASF.
25. Richard Murphy, "Chromium in the Timber Preservation Industry," in *Chromium (VI) Handbook,* eds. Jacques Guertin, James A, Jacobs and Cynthia Avakian (Boca Raton, FL: CRC Press, 2005); Barry A. Richardson, *Wood* Preservation (Lancaster, UK: The Construction Press, Ltd., 1978); D. D. Nichols, *Wood Deterioration and Its Prevention by Preservative Treatments* (Syracuse, NY: Syracuse University Press, 1973).
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Industry Tomorrow," *Forest Products Journal* 50, no. 9 (2000): 12–15.
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28. "Response to Requests to Cancel Certain Chromated Copper Arsenate (CCA) Wood Preservative Products and Amendments to Terminate Certain Uses of Other CCA Products," *Federal Register* FR 68 (9 April 2003): 17366–17372.
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30. R. J. Bauer, "Glass Industry Requirements," in *Arsenic* (see n. 8).
31. Arsphenamine was marketed under the trade name Salvarsan and was also widely known as Compound 606 or Ehrlich-606, so called because it was the 606th synthesized arsenical which was found to be clinically effective against *T. pallidum*, the infective organism, and yet have acceptable side effects.
32. C. E. Anderson, "Arsenicals as Feed Additives for Poultry and Swine," in *Arsenic* (see n. 8); "Arsenic in Chicken Production, "*Chemical and Engineering News* 85, no. 15 (2007): 34–35; "Pfizer Suspends Sales of Chicken Drug With Arsenic," *New York Times,* 9 June 2011, p. B2.
33. R. K. Willardson, "Arsenic in Electronics," in *Arsenic* (see n. 8).
34. Rachel Carson, *Silent Spring* (New York: Houghton Mifflin Co., 1962); Thomas R. Dunlap, ed., *DDT, Silent Spring, and the Rise of Environmentalism* (Seattle: Univ. of Washington Press, 2015). This collection of essays discusses the displacement of arsenicals by DDT, the consequences, and public reaction.
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36. S. S. Pinto, P. E. Enterline, V. Henderson and M. G. Varner, "Mortality experience in relation to a measured arsenic trioxide exposure," *Environmental Health Perspectives* 19, no. 8 (1977): 127–130; P. E. Enterline and G. M. Marsh, "Cancer among workers exposed to arsenic and other substances in a copper smelter," *American Journal of Epidemiology* 116, no. 6 (1982): 895–911.
37. Manuel Velasquez, *Business Ethics: Concepts and Cases*, 3rd ed. (Englewood Cliffs, NJ: Prentice Hall, 2002), 267–68.
38. William D. Ruckelshaus, "Science, Risk and Public Policy," *Science* 221, no. 4615 (9 September 1983): 1026–1028; Marianne Sullivan, *Tainted Earth: Smelters, Public Health, and the Environment* (New Brunswick, NJ: Rutgers University Press, 2014) provides a detailed and valuable analysis of the numerous political and regulatory issues related to arsenic and lead pollution associated with smelters at Tacoma, WA, El Paso, TX, and Bunker Hill, ID.
39. Philip Shabecoff, "Tacoma Gets Choice: Cancer Risk or Lost Jobs," *New York Times*, 13 July 1983, p. A1.
40. The workplace air limit for inorganic arsenic was 500 $\mu g/m^3$ as established by the Occupational Safety and Health Administration (OSHA) in 1968. The permissible exposure limit (PEL) was reduced by a factor of fifty to 10 $\mu g/m^3$ in 1975 and this remains the current standard. The standard also includes annual medical examinations of workers and numerous additional requirements. However, OSHA proposed a further reduction to 4 $\mu g/m^3$ in 1975.
41. "Asarco Pays $1.79 Billion to Fix Sites," *New York Times*, 10 December 2009; Anne Fischel and Lin Nelson, "Their Mines, Our Stories, Work, Environment, and Justice in ASARCO-Impacted Communities," Evergreen State College, www.theirminesourstories.org.
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44. "Organic Arsenicals; Product Cancellation Order and Amendment to Terminate Uses," EPA-HQ-OPP-2009-0191, 74 Fed. Reg. 188 (30 September 2009): 50187–50194.
45. Audrey Matteson and Matthew Polizzotto, "Arsenic Accumulation from Herbicides in Pond Water and Sediments Near Sod Farms and Golf Courses in North America" (paper presented at the Geological Society of America, Baltimore, MD, November 4, 2015), https://gsa.confex.com/gsa/2015AM/webprogram/Paper265550.html.
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47. "Response to Requests" (see n. 28).
48. "FDA to Withdraw Approval for Arsenic-Based Drug Used in Poultry," *Food Safety News* 1 (April 2015).
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