ARSENIC POLLUTION AND POISONING THROUGH THE AGES

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An Ode to Arsenic

I am an evil, poisonous smoke,
But when from poison I am freed,
Through art and sleight of hand,
Then I can cure both men and beasts.
But prepare me correctly, and take great care
That you faithfully keep watchful guard over me,
For else I am poison, and poison remain
That pierces the heart of many a one (Valentini, 1694).

Arsenic: A poison for the gods

- The name arsenic itself is derived from the Greek word, arsenikon, which means potent
- Arsenic was not one of the seven metals known to the ancients and although there was no “Arsenic Age”, the king of poisons has probably influenced human history more than any other element or toxic compound.

Arsenic: A poison for the gods

- Vulcan and Ceres

This enigmatic metal began its long association with human culture by poisoning the god (Vulcan or Hephaestus) who endeavored to find some use for it.

The deformity of Hephaestus, the mythical Greek god, Vulcan (his Roman counterpart) and the patron gods of smiths in cultures around the world can be attributed to the effects of exposure to toxic fumes of arsenic (and possibly lead).

Fools' Gold

The ancients believed that orphiment (As_2S_3) contained gold hence the name auropigmentum.

Arsenopyrite has been known as fools' gold since time immemorial.

Arsenic minerals in Paleolithic times

- The bright red-colored orphiment attracted the attention of human culture and was used as pigment in Paleolithic times
- Orphiment was found in a linen bag in King Tutankhamun's tomb, in wall paintings of the Theban necropolis and more extensively from the 18th Dynasty onwards

Arsenic minerals in Paleolithic times

- Orphiment and realgar were cited in the Akkadian texts as ingredients for ornamental painting and for cosmetic purposes
- Both Pliny and Strabo referred to several ancient mines that produce orphiment for painters

Fools' Gold

GAIUS (CALIGULA). 37-41

Gaius Aurelius Valerius Diocletianus (AD 240 - AD 311)

- Pliny described the failed effort of Emperor Caligula to extract gold from orphiment
- In 260 AD, Emperor Diocletian was so infuriated by the failure of Egyptian alchemists to extra gold from orphiment that he collected all books dealing with transmutation and burned them.

Alchemical symbol for arsenic

The alchemists who relied on orphiment to make gold were probably rewarded with arsenic poisoning rather than materially for their efforts

Discovery of Arsenic

Albertus Magnus (1193-1280),

The history of human attempts to isolate and study elemental arsenic is as frustrating as the effort to find a universal antidote for its poisonous properties.

Albertus Magnus (1193-1280), a German Dominican scholar and alchemist, is generally credited discovering elemental arsenic

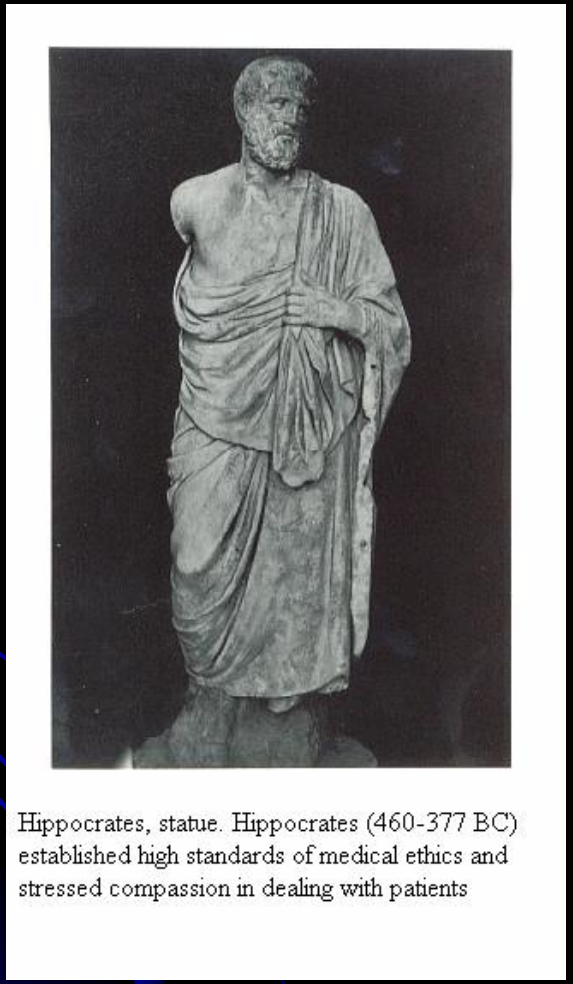
Medicinal uses and iatrogenic poisonings: Ancient China

- Realgar was produced from several places in ancient China.
- It is said to be spermatic and masculine and of the *Yang* principle
- By contrast, orphiment is female and of the germinal or Yin principle
- Its antifebrile, prophylactic, emetic, expectorant, deobstruent, arthritic, anti-helmintic and antidotal properties were noted in *Pen Ts'au* (2nd century BC) and earlier works

Medicinal uses and iatrogenic poisonings: Ancient China

- Arsenic was a common ingredient in metallic elixirs consumed by the ancient Chinese in their quest for longevity and/or immortality.
- Sun Ssu-Mo, the great alchemist and pharmacist gave the secret recipe for gold elixir (chin tan) as 8 oz of gold, 8 oz of mercury, 1 lb of realgar and 1 lb of orphiment
- Arsenic must bear much of the blame for the iatrogenic poisonings of many ancient Chinese alchemists and their patron emperors
- Even today, many traditional Chinese medicinals still contain high levels of arsenic

Medicinal uses and iatrogenic poisonings: Ancient civilizations of the Middle East

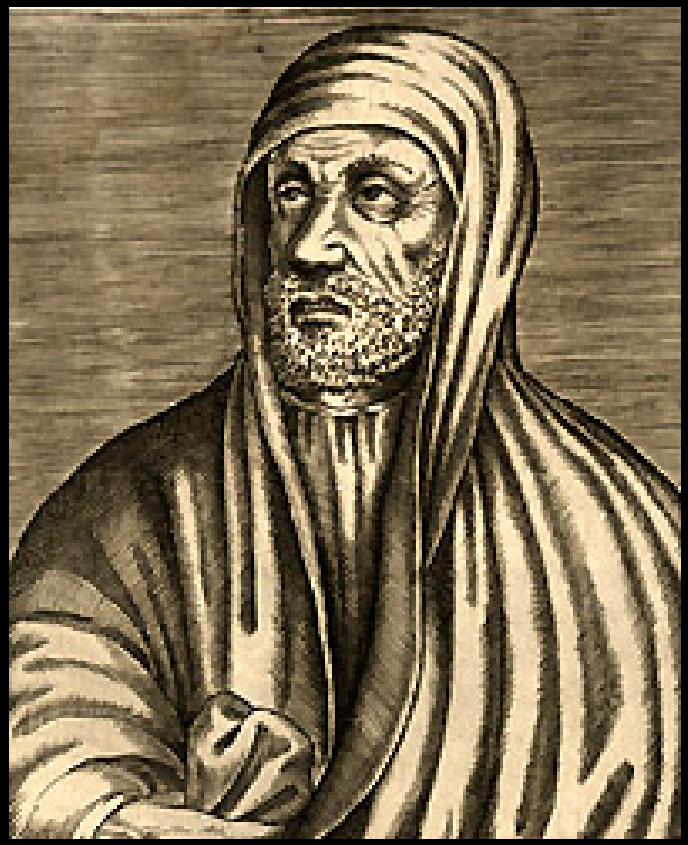


Hippocrates, statue. Hippocrates (460-377 BC) established high standards of medical ethics and stressed compassion in dealing with patients

- Arsenic was featured extensively in the materia medica of ancient civilizations of the Middle East
- Hippocrates, Galen, Celsus, Caelius Aurelianus, Aetius, Soranus and many other famous ancient Greek and Roman doctors prescribed orphiment and realgar for various curative purposes

Medicinal uses and iatrogenic poisonings: Middle Ages

- Arabian physicians added many more arsenic compounds to the materia medica handed down from the ancients



Avicenna (980 - 1037)

Medicinal uses and iatrogenic poisonings: Middle Ages

- Paracelsus who broke the rigid tradition of Galenic medicine gave cogency to the belief that there was a therapeutic window for toxic compounds in which clinical benefits can be had without achieving extreme toxicity.
- After Paracelsus, the medicinal qualities of arsenic and its compounds began to be touted throughout Europe in an ever-expanding manner.

SPRINGTIME OF ARSENIC POISONING

The period of 1700 to 1850 can be regarded as the spring time of arsenic poisoning when human beings were exposed to unprecedented levels of arsenic in their medicine, food, water and at work or accidentally.

The introduction of *Tasteless Ague Drop* or Fowler's solution (alkaline solution of potassium arsenite) in 1670 began the ascendancy of arsenic in western pharmacopoeia. By the end of the 19th century every major disease known was being subjected to arsenotherapy.

MEDICAL REPORTS

OF THE

EFFECTS of ARSENIC,

IN THE CURE OF

AGUES, REMITTING FEVERS,

AND

PERIODIC HEADACHS;

By THOMAS FOWLER, M. D.

Physician to the General Infirmary of the County of Stafford.

TOGETHER WITH A LETTER FROM DR. ARNOLD, OF LEICESTER, AND ANOTHER FROM DR. WITHERING, DESCRIBING THEIR EXPERIENCE OF THE EFFECTS OF ARSENIC IN THE CURE OF INTERMITTENTS.

Plurimum referre cenſemus, ſi Medici aliqui,
----------opus aliquod conficiant; de Medicinis probatis et experimentalibus, ad Morbos particulares.
VERULAMIUS de Augment. Scient. Lib. IV. Cap. II.

——Poiſons in ſmall doſes are the beſt medicines, and the beſt medicines in too large doſes are poiſonous.
WITHERING's Botanical Arrangement.

LONDON.

Printed for J. JOHNSON, No. 72 St. Paul's Church Yard, and WILLIAM BROWN, Corner of Eſſex Street, Strand.
MDCCLXXXVI.

Organoarsenicals become famous

Bunsen, Robert (1811 - 1899)

- Robert Wilhelm Bunsen (1811-1899) was the first to isolate a smelly compound, $C_4H_{12}As_2O_3$, to which the name cacodyl (stinking) was given by Berzelius.
- Although the daring experiment brought instant fame, Bunsen was nearly killed from inhaling the arsenic vapor and lost one eye to an explosion of the compound
- Organic arsenicals entered the Western pharmacopoeia towards the end of the 19th century.

Organoarsenicals become famous

German bacteriologist Paul Ehrlich won the 1908 Nobel Prize in physiology or medicine.

In his quest for a magic bullet in chemotherapy -- a drug that could destroy bacteria circulating in the blood stream without killing or seriously harming the patient or his organs -- Paul Ehrlich was able to synthesize Arsphenamine, renamed salvarsan afterwards, which dominated the syphilis therapy until the late 1940's and even later in the Far East where it was also used to treat yaws

Cure was worse than the disease

Treatment of syphilis with arsenic was a lengthy and unpleasant business; minimum duration was about 18 months and involved 20 injections of salvarsan and 30-40 injections of bismuth.

Thus, from 1700 to early 20th century, arsenotherapy was impressive and pervasive and at no other time in human history has the health of nations depended so much on one element.

Arsenic in warfare

Early Chinese alchemical texts recommended arsenic sulfides for making toxic smoke bombs or "holy smokes" for mass poisoning of soldiers -- one of the earliest references to chemical warfare.

Arsenic was cited as an ingredient of the devilish incendiary material used by Marcus Graccus to burn the Roman naval fleet

Wonder Weapon – The Greek Fire

Greek fire was invented during the reign of Constantine IV (641-668 AD). This wonder weapon caught fire spontaneously and was said to be impossible to extinguish. The secret of the Greek fire was carefully guarded (consisted of a mixture arsenic sulfide and potassium nitrate)

Arsenic in warfare

The Harmony policy ("gifts" of food laced with arsenic) in Australia deserves special mention in the annals of human infamy

This nefarious method was used by British settlers in the 1840's to wipe out a large percentage of the famished aboriginal population in the Manning River basin, Australia

Lewisite – “Dew of Death”

Early chemical warfare gases contained arsenic. Lewisite was first made in 1904 by combining acetylene and arsenic trioxide, by Rev. Julius Arthur Nieuwland, former Professor of Chemistry at the University of Notre Dame.

Lewisite (“dew of death”) causes skin lesions that are difficult to heal and was highly effective as a killing agent during WW I and was used by the Japanese against the Chinese in the Manchuria War of 1940 and

Lewisite – the sneeze gas

Lewisite was used by Sadam Hussein in the Iran-Iraq war of the 1980s and later against the Kurds in northern Iraq.

He also supplied it to the Sudanese government to use against the Sudan People's Liberation army

Arsenic in warfare

Cacodylic acid is registered as a silvicide (forest pesticide) and can defoliate and desiccate a wide range of plant species and was employed extensively in South Vietnam as Orange Blue.

Arsenic in warfare

The sphere of arsenic killing was greatly extended when arsenic was added to molten lead to increase the sphericity of the lead shot.

Dr. Thomas Holmes is credited with inventing or at least popularizing arsenic embalming as a sanitary practice during the American civil war so that soldiers (killed with arsenical lead bullets) were mercifully preserved with arsenic until given proper burial.

This practice further interweaves the history of arsenic with that of both the living and the dead.

Homicidal poisoning

The toxic effects of arsenic tend to be cumulative, enabling the poisoner to weaken the victim with small doses over a period of time before administering the fatal dose.

Notorious poisoners of ancient Rome

The notorious Agrippina, being intent on getting rid of Emperor Claudius (her cousin) but not daring to dispatch him suddenly and yet wishing not to leave him sufficient time to make new regulations regarding succession to the throne, used such a poison to deprive him of his reason and gradually consume him.

Later, the wicked emperor Nero (Agrippina's son) used the same poison to dispatch of Britannicus who was in line to succeed Claudius.

Homicidal poisoning

Arsenic became practically synonymous with poison during the Middle Ages when the art of secret poisoning became part of the social and political life.

In late 1600's, the infamous Tophana or Toffana of Palermo and Naples distributed her murderous oil marked *Manna of St. Nicholas of Bari* as charity to wives who wished to get rid of their husbands. It is estimated that thousands of men perished from A*qua della Toffana* which became a generic name for secret poisons sold widely in Europe between 1630 and 1730.

Homicidal poisoning

In the court of France, there were so many notorious poisoners that the name *poudre de succession* (inheritance powder) for white arsenic became a nightmare and a destabilizing influence as the heads of the great families came to regard all relatives and friends with extreme suspicion.

The punishment for the treacherous act was harsh: "If a Christian disavows faith or works magic or the mixing of poison and is caught in the act, the person shall be burned on a rack".

Pope Alexander VI (1492-1503)

The Spanish Pope died in 1503 after attending a banquet. His death was rumored to have been caused by arsenic-laced food intended for someone else. His children (Cesare and Lucrezia) invented La Cantellera (arsenic powder) and were among the most notorious poisoners in Italy

Mozart's mysterious death and hasty burial

Unfinished portrait of Mozart 1789. ~ Joseph Lange

Mozart himself suspected foul play. Some weeks before his death, he told Constanze that he was being poisoned: "Someone has given me aqua toffana and has calculated the precise time of my death." Mozart came to believe that the Requiem Mass, which a mysterious stranger had commissioned him to write, was for his own funeral service.

King George III (1738-1820)

King George III of England was instrumental in ending Seven Years War at Peace of Paris, 1763. He was a strong supporter of policies leading to American Revolution, opposed liberalization of colonial government in America. Analysis of strands of his hair in 2003 showed 17 ppm arsenic, 2.5 ppm mercury and 6.5 ppm lead. Arsenic probably came from the tartar emetic that was often prescribed for him.

President Zachary Taylor was not poisoned by arsenic

- The 14th president of the US was a fit and healthy man nicknamed “Old Rough and Ready” when he was elected into office. Shortly after breaking ground for the Washington Monument on July 4, 1850, the President, a hero of the Mexican War, fell ill and died suddenly.
- At a request of one of his descendants, his remains were exhumed in 1999 and analysis of his fingernail and hair showed only trace amounts of arsenic, lead and mercury.

Napoleon Bonaparte (1769-1821), Emperor of France 1804-14

Did the British poison him in prison?

Other deep mysteries of arsenic

How prevalent were death lamps in which the oil and wax impregnated with arsenic were burned to poison victims slowly?

Arsenophagy

Habituated eating of arsenic is deeply rooted in folkloric medicine, religious beliefs and harmful magic.

The famed arsenic eaters of Styria (Austrian Alps) take a special place in the history of pharmaco-toxicology. Their antics served to minimize the public concern about the dangers of environmental and occupational exposure to arsenic and perpetrate the myth that arsenic may be good for the human race.

Somewhat related to arsenophagy of Styria was the prospective arsenic prophylaxis of the fakirs (snake charmers) said to have been widespread in Persia during the middle of the 19th century

Widespread environmental contamination with arsenic

The efficacy of arsenical insecticides was discovered serendipiciously in 1867 when an exasperated farmer threw some Paris green (copper arsenate) paint on beetle-infested potato plants and came back a few hours later to find that all the bugs were dead

The problem of the phytotoxicity of Paris green and London purple was solved with the introduction of lead arsenate (especially for gypsy moth) in 1892 which was gentler to the foliage and its bug killing properties were more catholic.

For nearly three-quarters of a century, arsenic remained unchallenged as the protector of American crops until the introduction of synthetic organic insecticides during World War II.

Widespread environmental contamination with arsenic

- Spray of lead and calcium arsenates marked the beginning of widespread intentional contamination of the environment from dissipative application of a highly toxic material
- Over the years, the spraying of over one billion pounds of arsenical pesticides on American crops has left a legacy of contaminated soils and groundwater that will remain with us for a long time.

Widespread environmental contamination with arsenic

Elevated levels of arsenic from natural and industrial sources have recently been reported in groundwater in many parts of the world including Taiwan, China, India, Bangladesh, Thailand, Chile, Argentina, Mexico, Canada, United States.

Contamination of groundwater is global phenomenon

It is estimated that about 80million people in Bangladesh and 6 million people in China are at risk of being poisoned by ingesting water with arsenic levels above 50 μg/L; worldwide, the at-risk population is estimated to be over 150 million.

Recent research continues to show how wedded we are to arsenic.

Arsenic in our daily lives

Pigments containing arsenic were employed in numerous consumer products including fancy and colored papers in magazines and children's books, sheets for cardboard boxes, labels of all kinds, advertising cards, wrappers for candies, confectionary and sweatmeats, playing cards, lamp shades, paper hangings for walls and other purposes, artificial leaves and flowers, artificial wreaths, wax ornaments for Christmas trees and other purposes, children's toys, printed or woven fabric intended for use as garment, curtains, furniture coverings, painted India rubber dolls

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF CHEMISTRY—BULLETIN No. 86.
H. W. WILEY, Chief of Bureau.

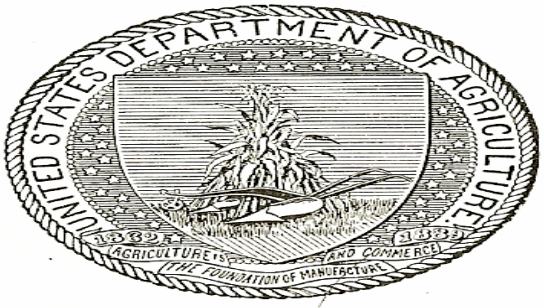
ARSENIC IN PAPERS AND FABRICS.

BY

J. K. HAYWOOD,
Chief, Insecticide and Agricultural Water Laboratory,

WITH THE COLLABORATION OF

H. J. WARNER,
Assistant Chemist.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

Arsenic in daily lives of people

Other uses for arsenic included Venetian and other blinds, leather cloth, printed table baizes, book cloth and fancy bindings, decorative tin plates, oil paintings, carpets, floorcloth linoleum, wallpaper, wall paint (Paris-Scheele's-Vienna-Emerald greens, King's or Naples yellow, magenta, and other anilin-based colors), boxes of water colors and surprisingly to give color to confectionery ornaments. In addition, arsenic was used in medicated soaps, embalming solutions, preparation of skins for stuffing, adhesive envelopes, glass, fly-powder and rat poison and sheep-dip. Practically everybody must have come into contact with these products.

Numerous cases of poisonings and fatalities following contact with arsenic in consumer products appeared frequently in the historical records from about 1820 onwards.