Return to Wine

Lead Poisoning and Rome

> "The bellows are burned, the lead is consumed of the fire; the founder melteth in vain: for the wicked are not plucked away. Reprobate silver shall men call them, because the Lord hath rejected them."
>
> *Jeremiah, 6:29-30*

A 1983 article in the *New England Journal of Medicine* by Jerome Nriagu, a geochemist, reopened a debate that had been dormant for almost two decades. There, and in a book published later that year, he argued that "lead poisoning contributed to the decline of the Roman empire." Yet a review by John Scarborough, a pharmacist and classicist, has criticized the book as "so full of false evidence, miscitations, typographical errors, and a blatant flippancy regarding primary sources that the reader cannot trust the basic arguments." Scarborough concluded that, although ancient authorities were aware of lead poisoning, it was not endemic in the Roman empire nor caused its fall.

A by-product of silver mining, the Romans extracted lead (Pb) from galena ore (PbS, lead sulfide), which was crushed and smelted (Pliny, *Natural History,* XXXIII.95, 159). The lead alloy then was further refined in a furnace made hotter still by blasts of air forced from a bellows. The oxidized lead (PbO, litharge), which was contained in a porous crucible of crushed bone ash, was absorbed, leaving behind a trace amount of silver in a process called "cupellation" (from the cupel used to collect the metal). The lead itself was recovered by smelting the bone ash again with galena, the lead oxide combining with lead sulfide to form metallic lead and sulfur dioxide ($2PbO + PbS = 3Pb + SO_2$).

Readily abundant, easily malleable, and with a low melting point (low enough, in fact, to melt in a camp fire), lead (*plumbum*) was ideal for the production of water pipes, which were fabricated by *plumbarii* (plumbers) from fitted rolled sheets in a variety of diameters (Vitruvius, VIII.6.1ff; Frontinus, XXXVIIff). Such pipes were used extensively by the Romans but also known to be a potential source of soluble lead. How then to reconcile the two realities?

Rome is situated on sedimentary calcareous soil, and the frequent cleaning of limestone encrustation (which accumulated approximately one millimeter per year) suggests that deposits of calcium carbonate ($CaCO_3$) in the pipes protected against corrosion and insulated against the introduction of lead into the water. Indeed, in his treatise on the aqueducts of Rome, Frontinus complains that "the accumulation of deposit, which sometimes hardens into a crust, contracts the channel of the water" (CXXII.1). The aqueduct at Nîmes, for example, had an accretion of calcium carbonate that constricted its channel by forty-six centimeters, more than a third of its width. Too, the water in lead pipes would have flowed continuously and not been in prolonged contact with the metal. And, as well as lead pipes, there were those made of clay. In *De Architectura* Vitruvius, who wrote during the time of Augustus, indicates that the Romans knew of the danger of lead and, consequently, that terracotta was preferred.

> "Water conducted through earthen pipes is more wholesome than that through lead; indeed that conveyed in lead must be injurious, because from it white lead

> [*cerussa*, cerussite or lead carbonate, $PbCO_3$] is obtained, and this is said to be injurious to the human system. Hence, if what is generated from it is pernicious, there can be no doubt that itself cannot be a wholesome body. This may be verified by observing the workers in lead, who are of a pallid colour; for in casting lead, the fumes from it fixing on the different members, and daily burning them, destroy the vigour of the blood; water should therefore on no account be conducted in leaden pipes if we are desirous that it should be wholesome. That the flavour of that conveyed in earthen pipes is better, is shewn at our daily meals, for all those whose tables are furnished with silver vessels, nevertheless use those made of earth, from the purity of the flavour being preserved in them" (VIII.6.10-11).

Columella, too, remarks on the advantage of terracotta pipes. "Rain-water is after all most suitable to the body's health, and is regarded as uncommonly good if it is conveyed through earthen pipes into a covered cistern" (I.5.2; cf. Celsus, who contends that rain water has the least amount of contamination, *De Medicina*, II.18.12). But rain water also is slightly acidic, having dissolved carbon dioxide in the atmosphere to form a weak solution of carbonic acid.

Rather than encrusted lead pipes, a more probable cause of chronic lead poisoning (plumbism or "saturnism" because its symptoms seemed indicative of the planet's characteristics) was the consumption of *defrutum* and *sapa*. Cato, Columella, Pliny, and Palladius (*On Agriculture*, XI.18) all describe how unfermented grape juice (*mustum*, must) was boiled to concentrate its sugar. "A product of art, not of nature," says Pliny (XIV.80), the must was reduced to one half (*defrutum*) or even one third its volume (*sapa*), and the thickened syrup used to sweeten and preserve wine and fruit that otherwise was sour or would spoil. Cato, for example, recommends that olives and pears be preserved in boiled must (VII.4) as does Varro (I.59.3). And Columella indicates that *defrutum* should always be boiled with quinces or some other flavoring (XII.20.2). Apicius, in *De Re Coquinaria* offers directions for preserving quinces in *defrutum* and honey (I.21) and added the rich syrup to many of his sauces to enhance the color and flavor of almost every dish, whether meat, fish, fowl, or fruit. (The fact that the reduction was used to color food indicates that red wine was used rather than white.)

The question is how the must was boiled and reduced, whether in pots of bronze or lead. If lead, there is a danger that the metal will be leached into the acidic juice. In *De Agri Cultura*, the earliest example of Latin prose (c.160 BC), Cato gives directions for reducing must in "a copper or lead vessel" over a slow fire, "stirring constantly to prevent scorching; continue the boiling, until you have boiled off a half" (CVII). Writing in the first century AD, Columella elaborates on this process.

> "Some people put the must in leaden vessels and by boiling reduce it by a quarter, others by a third. There is no doubt that anyone who boiled it down to one-half would be likely to make a better thick form of must and therefore more profitable for use....But, before the must is poured into the boiling-vessels, it will be well that those which are made of lead should be coated inside with good oil and be well-rubbed, and that then the must should be put in....The vessels themselves in which the thickened and boiled-down must is boiled should be of lead rather than of brass; for, in the boiling, brazen vessels throw off copper rust [*aerugo*], and spoil the flavour of the preservative....Must of the sweetest possible flavour will be boiled down to a third of its original

> volume and when boiled down, as I have said above, is called *defrutum*" (XII.19.1, 19.6, 20.1, 21.1; notice that the definition is not always consistent).

Theophrastus, a student of Aristotle, was the first to describe the production of copper-rust (copper acetate) from the reaction of the metal and wine lees, by which the acetic acid (vinegar) in soured wine reacts with copper oxide to form copper acetate (*De Re Metallica*, IX).

Pliny, too, recommends that the must be prepared in lead vessels.

> "Also boiled-down must and must of new wine should be boiled when there is no moon, which means at the conjunction of that planet, and not on any other day; and moreover leaden and not copper jars should be used, and some walnuts should be thrown into the liquor, for those are said to absorb the smoke" (XIV.136).

It would seem therefore that the must was boiled in cauldrons of lead, although Scarborough is reluctant to weaken his case, insisting that "one needs to read these texts carefully which mention a 'preference' for lead over bronze to realize that the Romans most often used bronze cauldrons (copper and tin in alloy), not those of lead." But copper and bronze are suspect as well. Pliny writes that "When copper vessels are coated with *stagnum* [a lead alloy], the contents have a more agreeable taste and the formation of destructive verdigris is prevented" (XXXIV.160) and that the best bronze was alloyed with ten percent lead and tin (XXXIV.95). Still, Scarborough insists that the short boiling time would not have contaminated the juice.

Aside from whether the must was boiled in lead, assumptions also have to be made regarding how much *defrutum* was added to sweeten and preserve the wine, the amount of wine consumed, and its lead content. Both Eisinger and Patterson et al. found that must reduced to one-third its volume contained approximately 1000 milligrams of lead per liter. If, as Columella recommends (XII.20.3), one sextarius of *defrutum* should be mixed with one amphora of wine, which held approximately 26 liters, the resulting proportion would be one part in forty-eight or almost 21 milligrams of lead per liter (2100 µg/dL), a concentration that certainly would induce symptoms of lead poisoning (even more so, if one follows Cato's recommendation of one part in thirty, XXIV).

Nriagu assumes the aristocracy of Rome to have consumed two liters of such wine a day (almost three bottles, which would seem to make alcoholism more suspect than lead poisoning) but estimates the lead intake from this amount to be much less, an average of 180 micrograms (µg) daily. Although the relationship between ingested lead and blood lead levels varies, he further estimates the total amount of lead absorbed in the blood from all sources to be 50 micrograms per deciliter (µg/dL). If correct, such a level would have significant physiological consequences, as reported by the U.S. Department of Health and Human Services. There is brain and kidney damage in adults with blood lead levels of 100 µg/dL; gastrointestinal symptoms such as colic, with levels of approximately 60 µg/dL; anemia with levels of 50 to 80 µg/dL; neurological symptoms with levels of 40 to 60 µg/dL; depressed sperm count with levels of 40 to 50 µg/dL; and increased risk of preterm delivery, low birth weight, and impaired mental development with maternal blood lead levels of 10 to 15 µg/dL. The physiological insult to children would be much greater.

His contention that "a large number of Roman aristocrats ingested more than enough lead with their foods and drinks each day to put them at risk for lead poisoning" may be correct. But to infer that the impact on fertility was one of the principle causes for the decline of the Roman empire is not. Twenty years before, Gilfillan had insisted that "lead poisoning is to be reckoned the major influence in the ruin of the Roman culture, progressiveness, and genius," a thesis convincingly refuted by Needleman and Needleman, who demonstrate that the decline of the Roman aristocracy can as easily be explained by a simple desire not to marry or to rear few or no children. Augustus sought to promote marriage and encourage procreation by legislation (the Julian laws of 18/17 BC and the *Lex Papia Poppaea* a generation later in AD 9). "And yet, marriages and the rearing of children did not become more frequent, so powerful were the attractions of a childless state" (Tacitus, *Annals*, III.25). Sheidel, too, in a review of the life span of emperors and aristocrats, dismisses any impact of lead ingestion on fertility: "Nor is there any need to suspect that the incidence of marital sterility in the Roman ruling class might have been much higher than in other groups, times, and places." Still, Nriagu insists that "one of the principle, probable causes of the internal weaknesses" of the Roman empire was lead poisoning of the aristocracy.

Certainly, the Romans knew lead to be dangerous, even if they did not associate it with their lead cooking vessels. Pliny speaks of the noxious fumes (sulfur dioxide) of the lead furnace (XXXIV.167; there was a four-fold increase in atmospheric Pb pollution during the Greco-Roman period), *cerussa* as a deadly poison (XXXIV.176, even though it was widely used as a medicine and cosmetic), and the power of *sapa* (and onion) to induce an abortion (XXIII.30). Soranus in his *Gynecology* (I.19.61) recommends that the mouth of the uterus be smeared with white lead to prevent conception. Galen (*De Antidotis*, XIV.144) and Celsus both provide an antidote for poisoning by white lead (V.27.12b), and Vitruvius remarks on the pernicious effects of water found near lead mines and its effect on the body (VIII.3.5, 6.11).

The earliest description of lead poisoning (mid-second century BC) is given in the *Alexipharmaca* (II.74ff) of Nicander, who speaks of "gleaming, deadly white lead whose fresh colour is like milk which foams all over." The poet describes a frothing mouth, asperity of the tongue, and dry throat, together with dry retching, chills, delusions, and overwhelming fatigue. But if lead poisoning had been endemic, it presumably would have been remarked upon at the time. And yet there is no mention of the fact until early in the seventh century AD, when Paul of Aegina, a Byzantine physician, described the malady. "I am of the opinion that the colic affection which now prevails is occasioned by such humours; the disease having taken its rise in the country of Italy, but raging also in many other regions of the Roman empire, like a pestilential contagion, which in many cases terminates in epilepsy, but in others in paralysis of the extremities, while the sensibility of them is preserved, and sometimes both these afflictions attacking together" (III.64).

Although *defrutum* would have added a burden of lead, it should be remembered that the Romans diluted their wine. Of the two liters that Nriagu estimates to have been drunk every day, if mixed with two parts water, only two-thirds of a liter actually would have been undiluted wine. (Although he does not provide a basis for such a quantification, an inscription from AD 153 indicates that junior members of the College of Aesculapius and Hygia were allotted two *sextarii* of wine a day, and senior members, nine *sextarii*, the equivalent of approximately one to five liters.) Too, smaller vessels have a larger surface area relative to their volume. The four-liter pot used by Patterson et al. to determine the amount of dissolved lead presumably would leach out more of the metal than the huge oiled cauldron mentioned by Columella (XII.20.3), in which ninety amphorae (approximately

2340 liters) of must remained after boiling.

Defrutum was only one of several remedies to sweeten or preserve potentially sour wine (Pliny, XIV.121). Sea water and resin also were used, as was lead acetate (sugar of lead), which is formed by treating litharge with acetic acid (the component that gives vinegar its sour taste and pungent smell). Martial accuses a wine merchant of Marseilles of shipping poisonous and overpriced wines to his friends and, indeed, being reluctant to visit Rome for fear of having to drink them himself (*Epigrams*, X.36). Pliny, too, complains that "genuine, unadulterated wine is not to be had now, not even by the nobility" (XXIII.1), ruefully remarking "So many poisons are employed to force wine to suit our taste--and we are surprised that it is not wholesome!" (XIV.130). Indeed, "So low has our commercial honesty sank that only the names of vintages are sold, the wines being adulterated as soon as they are poured into the vats. Accordingly, strange though it may seem, the more common the wine is today, the freer it is from impurities" (XXIII.34).

Columella regarded "as the best wine any kind which can keep without any preservative, nor should anything at all be mixed with it by which its natural savour would be obscured; for that wine is most excellent which has given pleasure by its own natural quality" (XII.19.2), cautioning that "care must be taken that the flavour of the preservative is not noticeable, for that drives away the purchaser" (XII.20.7). The best tasting wine, therefore, likely would not have been adulterated and presumably was the very wine drunk by the nobility, who supposedly were most at risk for lead poisoning.

More than wine (or water transported through lead pipes), the dainties and elaborate sauces prepared with *defrutum* by gourmands such as Apicius are likely to have been the primary source of ingested lead by the Roman aristocracy.

"What I tell you three times is true."

Lewis Carroll, *The Hunting of the Snark (I.8)*

A cautionary note: Again and again, one reads on the Internet that Hippocrates described lead colic in a man who was a metal worker, or that he was the first to do so and that this occurred in 370 BC. The primary source for these statements is almost never given, although the *Encyclopaedia Britannica Online* does say in its entry on *Occupational Disease: The preindustrial era* that "The first recorded observation of an occupational disease may be a case of severe lead colic suffered by a worker who extracted metals. It is described in the third book of *Epidemics*, attributed to Hippocrates." There is mention of painful colic and constipation in Part 8 of that book, but the symptoms are not attributed to lead nor to lead workers. It is facile, therefore, to assume that, because Romans used lead and reported symptoms concomitant with lead poisoning, they were caused by lead--or, to phrase it another way, that if lead poisoning can have almost any symptom, then almost any symptom can be attributed to it. While Hippocrates may have known about lead poisoning, Waldron cautions that he "did not describe it in any of the books which have come down to us."

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