**Devlin M. Gualtieri**

## Get the Lead Out

You wouldn't think that lead was important, given that fewer than one out of every ten billion atoms in the universe is an atom of lead. Closer to home, the odds of finding lead are a little better. One out of every million atoms of the earth's crust is lead. Because of its useful properties, humans have mined vast quantities of lead since antiquity. We have been aided by the simple chemistry required to extract lead from its ore, galena, a combination of lead and sulfur. Lead is refined from galena simply by heating it in air to drive off the sulfur and to form an oxide of lead. This oxide is then heated with carbon to release the oxygen as carbon monoxide, leaving a mostly pure form of lead. Lead was an attractive material to our ancestors. It is lustrous and malleable, like gold and silver, but it has a conveniently lower melting temperature. More importantly, lead was cheap.

The Romans made extensive use of lead and its compounds for piping, cosmetics, wine goblets, and ceramic glazes. Lead, however, has a dark side. It is a toxic material that has significant health consequences if it is inhaled or ingested. It has even been conjectured that one cause of the decline of the Roman Empire was lead poisoning of its ruling class. Lead would be dissolved into wine from goblets, and lead compounds were sometimes intentionally added to wine to improve flavor. You may think that the health risk of lead is a recent discovery, but the ancients also recognized some of the dangers of lead. A peculiar malady caused by ingestion of lead was named Saturnine Gout, after the Roman god Saturn, who was associated with the metal. The word *saturnine* expresses the mental state associated with lead poisoning.

Lead was a fairly common commodity metal in the last century, but its use has declined because of the potential health risks. Efforts to remove lead from consumer items have accelerated in the last few decades. Some of us may remember that the simulated icicles on holiday trees, now made from aluminized mylar plastic, were once lead. Lead compounds were common pigments for paints; homes had lead water pipes; and automotive fuels had lead anti-knock additives. In fact, the word *plumbing* is derived from the Latin word for lead, *plumbum*, and scientists use the symbol Pb for lead. According to the U.S. National Academy of Science, the annual demand in the United States for lead had reached about ten pounds per citizen by 1980.

Leaded paint for residential use was banned in the United States in 1978, but it is still present in some older homes and buildings. Lead carbonate, or white lead, was used in paint because of its ability to hide underlying colors. The government has estimated that nearly 5 percent of preschool children have had an unacceptable exposure to lead. The lead limit for paint in the United States is now 300 parts per million (ppm).

Lead was introduced into gasoline in the1920s in the form of tetraethyl lead (TEL), a compound of lead and four organic molecules. TEL causes gasoline to burn at a slower rate to reduce engine "knock." The health problems of TEL were first discovered among formulation-plant workers, but only in 1973 did the EPA begin to regulate TEL. TEL is harmful not only in itself, but burning TEL in gasoline also causes a constant deposition of lead in solid form as lead oxide along urban roadways. The lead oxide is then tracked into homes to be inhaled or ingested. Another toxic compound of lead, lead-bromide gas, is produced by combustion of fuels containing ethylene dibromide. The TEL content allowed in gasoline was reduced to a tenth of a gram of lead per gallon in 1982, and lead for most vehicles was finally banned starting in 1996. TEL is still allowed in fuels for racing, farm machinery, and aircraft. Vehicles with catalytic converters cannot use leaded fuels because the lead will "poison" the catalyst and kill the function of the converter, which burns waste hydrocarbons in the exhaust.

So, your house is of recent construction, it has no lead paint, and your automobile does not use leaded fuel. Then what is the highest concentration of lead in your house? You may have remembered that car batteries contain a huge quantity of lead, but there are other sources of household lead. Your curio cabinet may contain items of leaded glass. Lead oxide is added to glass because its high refractive index adds a sparkle to cut glass. If we look past these items, the next greatest quantity of lead may be in your computer. The integrated circuits and other components are soldered to their wiring boards with a solder that is about 60 percent lead and 40 percent tin. The lead in this form is fairly safe because the alloying with tin significantly reduces lead's chemical activity. Your computer monitor is likely to have leaded glass to protect you from x-rays, but the lead is stable in this form as well because it is much like leaded-crystal glassware. The real problem is when consumers scrap their computers for the next model, something that happens about every three years. If these computers end up in landfills, acidic ground water can leach lead into the aquifer, although recent research indicates that the EPA estimates for leach rates may be too high.

More than twenty-million new personal computers are purchased in the United States each year. A television and a CRT computer monitor contain lead in rough proportion to

the screen area, and they can contain anywhere from three to eight pounds of lead. The National Safety Council (NSC) estimates that a combined total of 10,000 televisions and personal computers are taken out of service *each day*. The NSC also estimates that by the year 2007, about five-hundred million personal computers will have been scrapped in the United States alone. According to Collective Good International, one-hundred million cellphones are discarded annually. The EPA estimates that in the year 2000 more than four million tons of electronic waste were dumped into landfills, and the trend is increasing.

Government and industry are taking action on electronic waste. The European Union (EU) *Restrictions on Hazardous Substances* (EU RoHS) directive outlaws all but trace quantities of lead, cadmium, mercury, and high-valence chromium in nearly all electronic devices. The RoHS directive, which will be in force July 1, 2006, specifies a lead limit of 1,000 ppm, somewhat higher than the U.S. limit of 300 ppm for paint. Computer manufacturers have already begun to reduce the amount of lead in their products. As early as April of 2004, VIA, a major computer-motherboard manufacturer, introduced the first lead-free computer motherboard. Dell Inc. has announced computers meeting the EU RoHS directive, and Dell includes information about its lead-reduction program on its web site. Japanese electronics-manufacturer NEC has announced that it will also meet the lead-free directive. Taking the lead out of electronic circuits is not easy. Whereas the conventional lead-tin solder melts at about 180° C, the accepted replacement tin-silver alloy with minor additions melts at about 215° C. This significant temperature difference complicates component specifications and manufacturing processes. Furthermore, lead-free solder fractures more easily than leaded solder, which can lead to broken connections on circuit boards.

According to NSC estimates, less than 10 percent of electronic waste was recycled in 2000. Germany currently requires equipment manufacturers to recycle their products when returned by consumers. This recycling mandate soon will be applied to the entire EU via the EU *Waste Electrical and Electronic Equipment* directive. At the end of 2003, PC manufacturers in Japan were required to accept unwanted household PCs for recycling. Japanese consumers pay about thirty dollars per computer for this recycling. Japanese industry generally has been at the forefront of recycling efforts that have included recycling washing machines, refrigerators, air conditioners, televisions, and PCs.

Some states have not waited for the federal government to act on electronic waste. California has added a recycling fee to all sales of CRT computer monitors. It also has passed laws that mirror the EU RoHS and recycling directives. Recycling electronic waste is not cheap. The cost of adequately disposing of a PC is about thirty dollars, precisely what is charged in Japan, but there is a human cost as well. Most recycling in the United States is exported to other countries, notably China and India, and environmentalists are concerned that we are outsourcing our electronic-waste problem, rather than addressing it properly. Recycling merely shifts the environmental problem to a third-world country. A United Nations report in March 2004 suggests that extending the life of PCs, typically by upgrades, is the best way to reduce electronic-waste hazards.

Unfortunately, the spotlight on electronic waste makes it appear that this is the major problem. Lead in electronic products comprises less than 1 percent of total lead use. Storage batteries use more than 80 percent of the world's lead and ammunition about 5 percent. Five percent of the world's lead is still used in paints. If the world really wants to "get the lead out," it needs to look past electronic waste.

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