# Lead Use in Ammunition and Automotive Wheel Weights

An Examination of Lead's Impact on Environmental and Human Health, the Alternatives to Lead Use, and the Case for a Voluntary Phase-Out

By

Ryan Bodanyi

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Thesis Advisor: Professor Steve Brechin
Thesis Reader: Professor Sally Churchill

# Abstract

Lead is a potent toxin, capable of harming environmental and human health. Although lead's toxicity has been known for decades, the federal government has often proven reluctant to regulate it. Nor has this reluctance yet abated: although mounting evidence has suggested that lead use in ammunition and in automotive wheel weights can create severe hazards, the federal government has shown no inclination to act.

In this study, I examine the hazards that are posed through these uses of lead. Lead ammunition, when used at indoor ranges, can cause lead poisoning in humans; when used outdoors it can cause lead poisoning in a wide variety of waterfowl and wildlife. In both instances, the use of lead ammunition can lead to environmental lead contamination. Alternatives to lead do exist, and although they can be more expensive, none pose the same grave risks to environmental or human health. Lead wheel weights also pose a health threat, as they are quickly ground into hazardous lead dust after falling off their host vehicles on highways and city streets. The first study of this phenomenon, a visual survey of Albuquerque thoroughfares, estimated that 3.3 million pounds of lead are deposited annually on urban roads and freeways through lost wheel weights. My own study, a visual survey of Ann Arbor thoroughfares, concludes that anywhere between 6 million and 10 million pounds of lead may be deposited on the nation's highways annually. As in the case of lead ammunition, reasonable alternatives to the use of lead in wheel weights exist, at a cost that approximates but somewhat exceeds that of lead.

The fact that future regulation seems unlikely should not dissuade producers from adopting lead alternatives right now. Indeed, according to the doctrine of producer responsibility, the duty to act in the public interest rests with manufacturers and corporations, even in the absence of federal oversight. Given the severe health and environmental impacts of lead exposure, and the tremendous lead depositions that result from lead use in ammunition and in wheel weights, producers should act now to discontinue these uses of lead and to switch to safer alternatives.

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# Section One
## Introduction

Lead is a soft, gray, versatile metal that has been used by humans for over 5,000 years. Its toxicity to humans has been known for nearly as long. Miners and workers suffered from lead poisoning among the ancient Greeks and Romans long before the birth of Christ. However lead is still used in many applications today, and this widespread use has made lead exposure a concern for every living human being. According to the National Research Council, modern human beings have lead burdens 300-500 times those of our prehistoric ancestors.[1] Lead concentrations in North Americans today are 100-1,000 times those of pre-Columbian Americans,[2] while the current safety standard for lead—10 micrograms per deciliter of blood—exceeds pre-Columbian blood lead levels by a factor of 625.[3]

This increased exposure has made lead into a potent public health threat. The American Academy of Pediatrics has estimated that between 2 and 4 million American children today have enough lead in their blood to diminish their IQ, reduce their physical stature, damage their hearing, decrease their hand-eye coordination and impair their ability to pay attention in school. These losses are permanent, according to the Academy, and they translate into reduced educational attainment, diminished job prospects, and decreased earning power.[4]

Lead is also an environmental toxin. High lead levels have been associated with reduced species diversity,[5] diminished invertebrate reproduction,[6] and neurological changes in fish.[7] Millions of waterfowl died from the ingestion of lead shot before it was banned for waterfowl hunting in 1991.[8] Lead can adversely affect riparian water quality and aquatic ecosystems, and it is a persistent contaminant in urban runoff.[9] The National Research

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[1] National Research Council, *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations* (Washington, D.C.: National Academy Press, 1993). Page xii.

[2] Patterson CC, Ericson J, Manea-Krichten M, Shirahata H. 1991. "Natural levels of lead in *Homo sapiens sapiens* uncontaminated by technological lead," *Sci. Total Environ.* 107:205-36

[3] A. Russell Flegal and Donald R. Smith, "Lead Levels in Preindustrial Humans," *New England Journal of Medicine* Vol. 326 (May 7, 1992), pgs. 1293-1294.

[4] Committee on Environmental Health, American Academy of Pediatrics, "Lead Poisoning: From Screening to Primary Prevention," *Pediatrics* Vol. 92 (July 1993), pgs. 176-183.

[5] 1999 Annual Air Quality Report for Michigan, p. 23.

[6] *National Air Quality and Emissions Trends Report, 1998*. EPA 454/R-00-003. March 2000. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

[7] 1999 Annual Air Quality Report for Michigan, p. 23.

[8] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.

[9] University of Wisconsin-Extension, Wisconsin Department of Natural Resources, *Urban Runoff: How Polluted Is It?* 1995. Available at: www.env21.com/DocShareLight/Upload/Project12/URBAN%20RUNOFF(1).doc

Council estimates that 300 million tons of processed lead remains in the environment,[10] where it is likely to threaten human and environmental health for generations to come.

Progress has undoubtedly been made. The use of lead was banned from paint in 1978 and from gasoline in 1986. Blood lead levels in the U.S. population have plummeted since their high in the 1970s, and this reduction has been trumpeted as a public health triumph. However this triumph came far later than it might have, and has achieved less than it could have. Lead regulations were often adopted only reluctantly by the government, and only over the fiercest objections by the lead industry.[11] One Yale University physiologist had warned as early as 1923 that the use of lead in gasoline would fill cities with poisonous fumes,[12] while most of the industrialized world had banned the use of lead in paint by 1934.[13] Yet in the United States these uses of lead were allowed to continue.

Today lead is used in a variety of applications. Lead can often be found in solder; seals; ballast; blinds; ceramics; candle wicks; leaded glass; lead-acid batteries; bullets and shot; PVC; and in automotive wheel weights, brake linings, fuel tanks, and vibration dampers.[14] Although safer alternatives to lead often exist, producers have been slow to relinquish its use, even in the face of growing evidence that these uses pose a continuing environmental and health threat.

In the following chapters I examine the threat posed by two continuing uses of lead. Lead wheel weights and lead ammunition have both come under increasing scrutiny in recent years, as a growing body of evidence has suggested clearly and unequivocally the threat that they pose to human health and the environment. Both uses are entirely unnecessary; safer alternatives exist and are comparable in both expense and performance. The fact that both uses nevertheless continue is unfortunately due to the  unwillingness of producers to switch to these safer alternatives.

The government should not have to legislate these changes; producers should initiate them willingly, in the interests of public health and the common good. The doctrine of producer responsibility states as much; it "places responsibility for the environmental impact of a product onto the producers of that product."[15] This, the doctrine argues, is where that responsibility should rightfully belong. Government will always be an inefficient tool with which to protect the public's health, operating slowly and clumsily

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[10] National Research Council, *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations* (Washington, D.C.: National Academy Press, 1993). Page 18.
[11] Peter Reich, *The Hour of Lead; A Brief History of Lead Poisoning in the United States Over the Past Century and of Efforts by the Lead Industry to Delay Regulation*, Environmental Defense Fund, Toxic Chemicals Program.
[12] The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/history_how.html
[13] The *Democrat and Chronicle* newspaper, accessed January 19, 2003. See http://www.democratandchronicle.com/news/extra/lead/1doctor.shtml
[14] The Lead Information website, accessed February 4, 2003. See http://www.leadinfo.com/USES/today.html
[15] Scottish Environmental Protection Agency website, accessed November 30, 2002. See http://www.electronics-scotland.com/environment/Environment_article.cfm?EnvironmentID=6

within the fast-paced market economy. Legislators were clamoring for a ban on leaded paint more than twenty years before the ban was passed, but this twenty-year process would have been unnecessary if American manufacturers had adopted the paintmaking technology of their French and British counterparts. A similar pattern is being repeated today. Lead production, in the words of the National Research Council, "evolves into tomorrow's background exposure, and despite reductions in the use of lead for gasoline, overall lead production continues to grow….Federal agencies have not addressed the impact of future increases of lead in the environment."[16]

It seems unlikely that the United States will soon adopt the European Union's phase-out of lead wheel weights,[17] or Denmark's total ban on leaded ammunition.[18] The producers of each will therefore be faced with a choice: should they switch to safer, cleaner, reasonably-priced alternatives, or should they continue to market leaded products that poison the environment and damage human health?

Rarely is there as clear a choice to be made.

## Thesis Methodology

The information contained herein was obtained in one of two ways: through literature review or primary research. The bulk of my thesis relies upon a literature review; empirical research was conducted for the automotive wheel weight section, but nothing else.

***Literature review.*** Research for this thesis has been conducted off and on for the past two years. Originally, the intent had been to focus simply on lead use in automotive wheel weights—a use that has only recently become a subject of study and concern. During the course of my research, however, I discovered that lead use in ammunition presented similar risks to environmental and human health, and that it could, like lead use in wheel weights, be phased out quickly and easily. Given their similarities, I decided to examine both uses in my report and present them as dual examples of the need for producer responsibility.

Preliminary research for this report was conducted between September and December of 2001, utilizing the resources of both the University of Michigan library system and the Auto Project of the Ecology Center of Ann Arbor. Very little literary research was conducted between January and June of 2002, when I was studying abroad in England. During the summer months of 2002—from June until September—I lived in Washington DC, and visited the Library of Congress twice weekly to further research this report.

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[16] National Research Council, *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations* (Washington, D.C.: National Academy Press, 1993). Page 18.
[17] 2002/525/EC, Commission Decision of 27 June 2002 Amending Annex II of Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles. *Official Journal of the European Communities* June 29, 2002 L170/81.
[18] International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Tin%20Shot.htm

Their databases—several of which are not available here at the University of Michigan—were of particular use to me. Final research for this thesis was conducted through the University of Michigan library system, from September of 2002 through late February of 2003.

***Primary research.*** I conducted primary research for this report in September and October of 2001 and January and February of 2002, in Ann Arbor, Michigan, and Oxford, England, respectively. This research was meant to duplicate, confirm, and expand on Dr. Robert A. Root's groundbreaking study on the deposition of automotive wheel weights (explored in detail on page 46).[19] Like Dr. Root, I intended to survey city streets for fallen lead weights; I hoped to conduct surveys both in Ann Arbor and in Oxford, where I knew I would soon be studying. The idea of conducting a street survey in England was appealing, as it would allow me to compare and contrast the rate of wheel weight deposition across international boundaries. Although the idea seemed promising, the survey did not proceed as I had anticipated.

On three occasions in January and early February, I surveyed a one-mile stretch of Parks Road, near downtown Oxford. I was unsuccessful in collecting any wheel weights on these occasions, and I discontinued my street survey thereafter. I later discovered that the efficiency of the street cleaning crews in Oxford had been my undoing; they swept the streets no less than twice per week. This frequent sweeping, when combined with the reduced traffic count of Parks Road, contributed to my findings.

I selected Parks Road as my survey location because I could walk to it with ease from where I lived, at St. Catherine's College. However I would have obtained the same results from any other street within walking distance. Given my transit constraints, it would have been infeasible for me to survey streets that were outside of walking distance with any regularity. On those rare occasions when I visited London, however, my brief and cursory glances at the curb did uncover a handful of wheel weights.

Although I was unable to quantify any rate of wheel weight deposition in England, deposition is certainly ongoing. This deposition is sure to pose serious threats to the environment and human health, even when the streets are swept as frequently as they are in Oxford. Street sweeping waste, I learned in Oxford, is dumped into the local landfill, where lead weights are likely to come into contact with corrosive agents and further contaminate the landfill leachate. Most streets in England, however, are not swept with any regularity, and the impacts of wheel weight deposition there are likely to parallel those described in Section Eight.

*Street survey.* The street survey that I conducted in Ann Arbor was far more successful, unmarred, as it was, by any street sweeping. For four weeks in September and October of 2001, I visually surveyed a one-mile stretch of Huron and Division roads twice per week.

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[19] Root, Robert A. *Lead Loading of Urban Streets by Motor Vehicle Wheel Weights.* Environmental Health Perspectives, Volume 108, Number 10. October 2000.

Division was surveyed between Catherine and Packard (.6 miles in length) and Huron was surveyed between Division and First (.4 miles in length).[20]

These streets were chosen due to their heavy traffic burden; Division supported 12,672 vehicles/day in 1997, the most recent reporting year available, while Huron supported 18,991 vehicles/day in 1998.[21] Multiplying the traffic count for Division by .6 and the count for Huron by .4 yields an adjusted daily traffic count for the two roads of 15,199.6 vehicles/mile. This number is considerably smaller than the 41,500 vehicles that traversed Dr. Root's area of study each day, but valid comparisons should still be possible on a per-vehicle basis.

My survey was conducted in a manner similar to that of Dr. Root; I walked along the curbside and retrieved any lead that I found along the outer curb, in the street, or on the sidewalk. In those locations where there was curbside parking (between Packard and East William on Division), I surveyed around and underneath parked vehicles.

*Parking structure survey.* Unlike Dr. Root, I conducted a second survey of parked cars in October of 2001, with the intention of determining how many had retained their quota of lead wheel weights. Parked vehicles in a number of area parking structures were surveyed and the number of wheel weights that they had lost determined, judged against an industry average of 2 wheel weights per tire.[22] Often three or more weights were found on a particular tire, suggesting that tires that contained their average quota of two weights might nevertheless have been missing one or more weights. Alternatively, tires that were found to have only one weight, and thus were assumed to have lost a weight, may not have needed more than one to balance the tire. Thus the actual number of wheel weights lost is impossible to determine for any one vehicle, but the average should hold for larger numbers of vehicles.

Similarly, the inner rim was not examined for the loss of wheel weights, only the outer rim. Instead, wheel weight losses from the inner rim were assumed to parallel those from the other rim. Thus, if a wheel weight was found to be missing from the outer rim of a tire, two weights were assumed to have been lost from the tire as a whole. This calculation introduces an added element of error, as it's doubtful that wheel weight losses from the inner rim parallel those from the outer rim so closely. Once again, the actual number of wheel weights lost is indeterminate for any one vehicle, but the average should hold for the larger numbers of vehicles surveyed in my study.

The only obstruction encountered in my survey was the presence of hubcaps. On those tires that lack hubcaps, the presence of wheel weights is easy to determine. However hubcaps obscure that part of the tire where wheel weights are typically affixed. The clip

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[20] Yahoo map service, accessed on December 11, 2002.
[21] Washtenaw Area Transit Study, contacted via phone on November 15, 2001.
[22] Lohse, et al. *Heavy Metals in Vehicles II*. Report compiled for the Directorate General Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities. Hamburg, Germany. July, 2001.

that holds the weights to the horn of the rim, however, remains visible despite the hubcaps, and these were used to determine the presence or absence of wheel weights on tires with hubcaps.

A total of 877 vehicles were surveyed over the course of four weeks. Although it is theoretically possible that vehicles surveyed in one parking garage were later resurveyed in another, in practice this was probably uncommon. Commuters tend to park consistently near their home or office, and the parking garages surveyed were spread throughout the city. The incidence of resurveyed-vehicles is likely to be low. However, as said before, the possibility cannot be discounted.

A similar survey was not conducted in England, or even attempted. Although the parking garages that are a fixture in Ann Arbor do not exist in downtown Oxford, parked cars were available and could easily have been surveyed. The fact that they were not is an oversight that I freely admit; distressingly, I did not consider the possibility until after I had returned to the United States.

## Thesis Organization

The following thesis is organized as follows:

- Section Two, a literature review, examines the impacts that lead exposure has on the health of children and adults; typical means of exposure; and the lead-polluted environments that we often encounter in our everyday life.
- Section Three, a literature review, provides a brief overview of lead's adverse impacts on the natural environment.
- Section Four, a literature review, surveys the federal history of lead regulation, and finds it lacking.
- Section Five, a literature review, introduces the concept of producer responsibility and explores its application around the world.
- Section Six, a literature review, explores the many health and environmental impacts of lead ammunition use at both indoor and outdoor firing ranges.
- Section Seven, a literature review, examines five of the alternatives to leaded ammunition and compares them to lead on the basis of price and performance.
- Section Eight, the product of a literature review and primary research, estimates the frequency with which leaded wheel weights fall off of their host vehicles, and the environmental lead burdens that may result.
- Section Nine, a literature review, compares the price and availability of the alternatives to lead wheel weights.
- Section Ten concludes this report by revisiting important points and discussing the applicability of producer responsibility concepts to lead use in ammunition and automotive wheel weights.

# Section Two

## Lead's Impact on Human Health

Lead exposure has long been known to have adverse effects on human health. Its effects are widespread and far-reaching, impacting nearly every system of the human body. The brain, kidney and reproductive systems of both genders are particularly affected by lead exposure.[23] Lead harms so many bodily systems because it disrupts enzyme systems that are mediated by other metals, particularly iron, calcium and zinc.[24] Exposure to lead causes such ailments as vomiting, headaches, and the loss of appetite; excessive exposure to lead can cause brain damage, stunt childhood growth and development, damage kidneys, impair hearing, and cause learning and behavioral problems. In adults, lead exposure has been shown to increase blood pressure and can cause digestive problems, kidney damage, nerve disorders, sleep problems, muscle and joint pain, and mood changes.[25]

Lead exposure is commonly estimated by measuring blood lead levels in units of micrograms per deciliter (µg/dL). The Centers for Disease Control and Prevention (CDC) set their level of concern at 10 µg/dL in 1991; this level was down from the 1970 level of 55 µg/dL.[26] This change reflects the new scientific research that has been conducted over the past thirty years, demonstrating that lead can have detrimental impacts on human health at levels that were previously considered safe.[27] In time, this standard too might change; according to the National Research Council, "There is growing evidence that even very small exposures to lead can produce subtle effects in humans. Therefore, there is the possibility that future guidelines may drop below 10 mcg/dL as the mechanisms of lead toxicity become better understood."[28]

Blood lead levels are valid only as a measure of recent lead exposure; over a period of 20-30 days, the body deposits lead to bone, where it accumulates throughout life.[29] Due to this process, chronic exposure to small doses of lead can result in a large long-term

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[23] Michigan State University, Department of Medicine, Division of Occupational and Environmental Medicine, *2001 Annual Report on Blood Lead Levels in Michigan*, November 2001, Available at http://web2.chm.msu.edu/oem/Lead/01LeadAnnualReport_ALL.pdf.
[24] 1999 Annual Air Quality Report for Michigan, p. 23.
[25] National Safety Council website, accessed July 18, 2002. *Lead Factsheet*. See http://www.nsc.org/library/facts/lead.htm.
[26] Juberg, Daland R., Ph.D. *Lead and Human Health: An Update.* Prepared for the American Council on Science and Health (ACSH), New York. July 2000.
[27] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf2.htm
[28] National Research Council, *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations* (Washington, D.C.: National Academy Press, 1993). Page 3
[29] Socolow, Robert and Valerie Thomas. *The Industrial Ecology of Lead and Electric Vehicles*. Journal of Industrial Ecology. Volume 1, Number 1, pp. 13-36. 1997.

accumulation.[30] This phenomenon is especially worrisome in the case of children due to their increased susceptibility to lead exposure. Normal exploratory behavior and hand-to-mouth activity in children between the ages of one and three can result in the repeated ingestion and inhalation of lead from household dust, paint and soil.[31] Early childhood lead exposure damage may persist into late adolescence and beyond, particularly in the case of the central nervous system.

## Childhood Exposure

Lead poisoning has been called an epidemic among American children.[32] Both the American Academy of Pediatrics and the Department of Health and Human Services have said that lead poisoning is "the most important environmental health problem facing young children."[33] More than two million children in the United States have blood lead levels that are high enough to adversely impact their ability to learn,[34] while approximately 2.7 million children have increased dental cavities due to high levels of lead exposure.[35] Nearly 4,800 children tested positive for high blood lead levels in Michigan in 2001; given that only 11% of the age group (and less than a quarter of those at highest risk of exposure) were tested, the true number of poisoned children is probably much higher.[36]

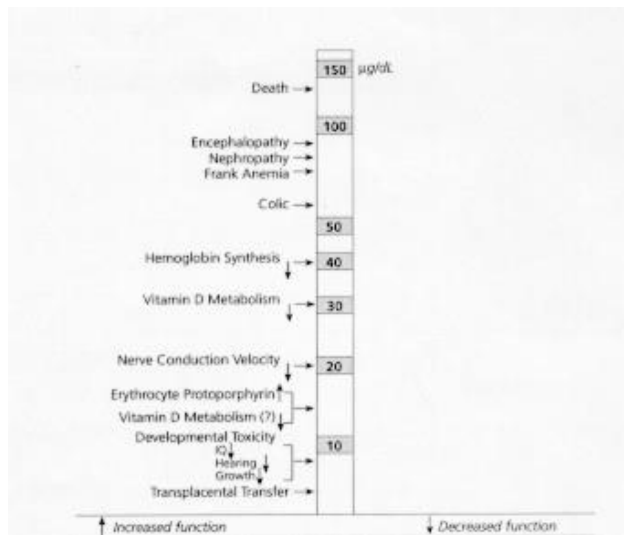


**Figure 1: The lowest observed effect levels of inorganic lead in children (µg/dL).**
Source: Agency for Toxic Substances Disease Registry, 1988. The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress. Atlanta: ATSDR.

Nearly all children are at risk for lead poisoning, although the risk is particularly high for children living in large metropolitan areas.[37] Childhood lead exposure is of particular concern because

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[30] National Research Council, *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations* (Washington, D.C.: National Academy Press, 1993). Page 99.
[31] Centers for Disease Control and Prevention website, accessed June 21, 2001. See http://cdc.gov/nceh/lead/faq/cdc97a.htm
[32] Philip J. Landrigan, "Commentary: Environmental Disease --A Preventable Epidemic," *American Journal of Public Health* Vol. 82 (July 1992), pgs. 941-943.
[33] Rachel's Hazardous Waste News #376, February 10, 1994.
[34] Committee on Environmental Health, American Academy of Pediatrics, "Lead Poisoning: From Screening to Primary Prevention," *Pediatrics* Vol. 92 (July 1993), pgs. 176-183.
[35] Moss, ME, Lanphear, BP, and Auinge, P. Association of Dental Caries and Blood Lead Levels. *JAMA* 281: 2294-2298 (1999).
[36] Michigan State University, Department of Medicine, Division of Occupational and Environmental Medicine, *2001 Annual Report on Blood Lead Levels in Michigan*, November 2001, Available at http://web2.chm.msu.edu/oem/Lead/01LeadAnnualReport_ALL.pdf.

lead disproportionately impacts young children and fetuses.[38] The developing bodies of infants, children, and fetuses absorb lead more easily than the developed bodies of adults; in children, studies have shown that approximately 50 percent of ingested lead is absorbed, while only 8-10 percent is absorbed among adults.[39]

In the 1970s and 1980s, approximately 9 out of every 10 children under the age of five had blood lead levels exceeding 10 µg/dL.[40] These children would have been considered poisoned by today's standards. However many children with blood lead levels below 45 µg/dL display no outward signs of elevated blood lead levels or illness.[41] When symptoms do appear, they may be non-specific symptoms such as fatigue, abdominal pain, constipation, headaches, irritability or aggressiveness.[42]

Nevertheless, the impacts of lead exposure can be severe. Widespread medical research has found that blood lead levels of approximately 10 µg/dL can lead to such health impacts as:

- The impairment of fetal development, particularly that of the central nervous system;
- Impaired mental ability and behavioral disorders in infants and children;
- The disruption of calcium balance and function in the organ systems[43] of infants and children.[44]

Similar research has found that blood lead levels of 25 µg/dL or less can lead to adverse health impacts such as:

- Lowered IQ and abnormal cognitive development and behavior in pre-school and school-age children;
- Decreased neurological ability which may persist into late adolescence;
- The elevation of hearing thresholds at 500, 1000, 2000, and 4000 Hz.
- Decreased gestation time, lower birth weight, and impaired cognitive development in fetuses.[45]

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[37] Update: Blood Lead Levels—United States, 1991-1994. MMWR Morb Mortal Wkly Rep 46:141-146 (1997).
[38] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment*. May, 2001, page 5.
[39] Minnesota Pollution Control Agency website, accessed September 6, 2002. See http://www.pca.state.mn.us/air/emissions/pb.html.
[40] Juberg, Daland R., Ph.D. *Lead and Human Health: An Update.* Prepared for the American Council on Science and Health (ACSH), New York. July 2000.
[41] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf2.htm
[42] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001, page 6.
[43] Agency for Toxic Substances Disease Registry, 1988. *The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress.* Atlanta: ATSDR.
[44] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf2.htm
[45] Ibid.

Chronic lead exposure at a young age frequently leads to reading disabilities, Attention Deficit Disorder (ADD), lower class standing, increased absenteeism, and lower vocabulary and grammatical-reading scores.[46] Fine motor skills may also be adversely impacted. Children with high blood lead levels are also more likely to develop anti-social behaviors and to be more aggressive, and are less likely to graduate from high school.[47]

Several studies of children chronically exposed to lead in early childhood have found that their educational ability has been impaired. The American Academy of Pediatrics recently reviewed 18 scientific studies and found that "the relationship between lead levels and IQ deficits was…remarkably consistent." According to the Academy, "A number of studies have found that for every 10 µg/dL increase in blood lead levels, there was a lowering of mean IQ in children by 4 to 7 points." An average loss of five IQ points, the authors write, puts 50% more children into the IQ 80 category, which is borderline for normal intelligence.[48]

In one study, two groups of children were followed into adulthood. One group had blood lead concentrations of 25 µg/dL, while the other had concentrations of 35 µg/dL. The latter group was found to be seven times less likely to graduate from high school; they were also six times more likely to have reading scores two grades below their expected level, after adjusting for socioeconomic status and parental IQ. The children with higher lead concentrations also had higher rates of absenteeism in their final year of school, were lower in class rank, suffered from poorer vocabulary and grammatical reasoning scores, and had longer reaction times and poorer hand-eye coordination.[49]

Poor and minority children are more likely to suffer from these poisonous effects of lead. A study conducted in the early 1980s found that while 25% of the white children living in poorer communities had lead levels above 15 µg/dL, only 7% of the white children living in areas of higher socioeconomic status had the same levels. African-American children living in poorer communities suffered from the worst rates of exposure: fully 55% of those sampled had blood lead levels in excess of 15 µg/dL.[50]

Although the average blood lead levels in U.S. children have declined significantly over the past 15 years—from 16 to 5 µg/dL—lead poisoning remains a fact of life for millions of American children. The American Academy of Pediatrics has said that "there are still many children at high risk of exposure"—far too many, as lead poisoning is a dangerous

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[46] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001, page 6.

[47] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf2.htm

[48] Committee on Environmental Health, American Academy of Pediatrics, "Lead Poisoning: From Screening to Primary Prevention," *Pediatrics* Vol. 92 (July 1993), pgs. 176-183.

[49] Needleman, Herbert L; Gatsonis, Constantine, *JAMA* Vol 263 No 05, A Low - Level Lead Exposure and the IQ of Children - A Meta - analysis of Modern Studies, February 1990

[50] Committee on Environmental Health, American Academy of Pediatrics, "Lead Poisoning: From Screening to Primary Prevention," *Pediatrics* Vol. 92 (July 1993), pgs. 176-183.

and damaging affliction. Fortunately, in the words of the Academy, "Childhood lead poisoning is preventable."[51]

## Adult Exposure

Average blood lead levels among adults in the United States range from 2.1 to 3.4 µg/dL; between 1.5 and 4.6 percent of the adults tested had blood lead levels above 10 µg/dL.[52] Of the 10,328 adults tested in the state of Michigan in 2001, 837 individuals (8.1%) had blood lead levels greater than or equal to 10 µg/dL. However this number is not representative, as the sample is self-selected and contains nearly all adult cases of severe lead poisoning in the state.[53]

Lead intake is often deposited to bone in adults, although it may be excreted with other bodily waste. Lead's half-life in bones can be over 20 years; this lead may lead to health impacts later on as it is slowly mobilized (for instance, during osteoporosis, pregnancy or chronic illness).[54] An iron, zinc, or calcium deficiency or a high-fat diet can increase the rate of lead absorption in both adults and children.[55]

Lead's impacts on adults vary, depending on the nature and frequency of lead exposure. Studies of workers in lead industries have found that chronic overexposure to lead may result in damage to the kidneys, gastrointestinal tract, peripheral and central nervous systems, reproductive system and blood-forming organs.[56] Workers in such fields as firearm training, battery production, lead smelting, printing, and pewter manufacturing were found to have increased levels of abnormal sperm, decreased sperm counts and sperm motility and alterations in certain hormones at blood lead levels ranging from 39 to 88 µg/dL.[57] Increased blood lead levels have been associated with decreased fertility in men at levels as low as 1.9 µm/L. Neurological impacts have also been found in workers with blood lead levels as low as 1.9 µm/L. Some research also indicates that increased blood lead levels are associated with increased blood pressure, with no apparent blood lead threshold for this effect (less than 0.48 µm/L).[58]

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[51] Ibid.

[52] Pirkle JL, Kaufmann RB, Brody DJ, Hickman T, Gunter EW, Paschal DC. Exposure of the US Population to Lead, 1991-1994. *Environmental Health Perspectives* 1998; 106:745-750.

[53] Michigan State University, Department of Medicine, Division of Occupational and Environmental Medicine, *2001 Annual Report on Blood Lead Levels in Michigan*, November 2001, Available at http://web2.chm.msu.edu/oem/Lead/01LeadAnnualReport_ALL.pdf.

[54] 1999 Annual Air Quality Report For Michigan, p. 23.

[55] *National Air Quality and Emissions Trends Report, 1995*. EPA 454/R-95-014. October 1995. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

[56] Winder, Chris, Reproductive and Chromosomal Effects of Occupational Exposure to Lead in the Male, *Reproductive Toxicology*, Vol. 3, pp 221-233, 1989.

[57] Ibid.

[58] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf2.htm

## Exposure During Pregnancy

Evidence indicates that lead was once widely consumed by women to induce abortions. Within the last century, female lead workers commonly experienced high rates of miscarriage and stillbirth and were therefore restricted from employment in certain lead industries in many countries. Exposure to lead (as low as 0.72 µm/L) before and during pregnancy is associated with pre-term delivery, low birth weight, an increased frequency of miscarriage and stillbirth. Problems in the early mental development of the fetus may also result from *in utero* lead exposure. However the level of exposure at which these problems begin to occur remains controversial.[59]

The physiological changes associated with pregnancy can modify both maternal and fetal exposures to lead and lead absorption. Examples may include:

- slowed gastrointestinal transport allowing increased absorption of lead;
- increased respiratory volume, leading to increased inhalation exposure;
- increased blood volume and body fat, influencing concentrations of lead in the blood and its distribution to body tissues.[60]

Women may be at a slightly greater risk of lead poisoning in general as many women suffer from low iron, which is commonly associated with increased lead absorption. While medical research on the physiological effects of lead on women hasn't been as extensive as that concerning men, it is likely that they experience similar increases in blood pressure and neurological symptoms at higher levels of exposure.[61]

## Lead and Violent Behavior

A growing body of evidence also suggests that lead exposure, particularly in childhood, can lead to a future of violent criminal behavior in certain individuals.[62] This correlation isn't ironclad, and doesn't hold in each individual case; rather a statistically significant association exists, in a broad sense, between lead exposure and future violent crime, after controlling for other potential variables. "Lead had its own independent effect on delinquency and adult criminality, separate from IQ," writes Dr. Deborah Denno, author of a watershed study on the subject.[63]

Her results were corroborated by another study of 301 boys in public school, conducted by Dr. Herbert L. Needleman of the University of Pittsburgh Medical Center.[64] Dr.

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[59] Ibid.
[60] Ibid.
[61] Ibid.
[62] Jane E. Brody, "Aggressiveness and Delinquency in Boys Is Linked to Lead in Bones," *The New York Times*, 7 February 1996, p. C9.
[63] Deborah W. Denno, *Biology and Violence: From Birth to Adulthood* (New York: Cambridge University Press, 1990).
[64] Herbert L. Needleman et al., "Bone Lead Levels and Delinquent Behavior," *Journal of the American Medical Association* 275 (February 7, 1996): 363.

Needleman explained, “I’m not saying that lead exposure is the cause of delinquency. It is a cause and one with the biggest handle to prevention. Lead is a brain poison that interferes with the ability to restrain impulses. It’s a life experience which gets into biology and increases a child’s risk for doing bad things.”[65] Other researchers have also linked lead exposure to violent behavior, and further studies in this field are ongoing.[66]

## Means of Exposure

Exposure to lead most often occurs in one of four ways: *in utero* exposure, skin absorption, inhalation and ingestion. Of these, ingestion is the most common route of non-occupational exposure in both children and adults.[67] In preschool children, lead is frequently ingested when they place their hands, toys and or other objects—and the dust or soil on those objects—into their mouths. This hand-to-mouth behavior is normal in preschool children, but in a lead-contaminated environment (e.g. soil, household dust or paint) it can pose serious threats to a child’s health.

Estimates of the amount of soil ingested by children vary widely, ranging from 4 to greater than 200 mg/day. The most common estimate is 60-100 mg/day, a rate which may increase one hundred fold in response to toddler mouthing behavior, pica (the habit of eating non-food objects), or other factors. Children with pica are at particular risk as they have been known to consume up to 20 grams of soil per day. Research has estimated that between 1% and 6% of preschool children have pica.[68]

The gastrointestinal tracts of children absorb approximately half of all ingested lead, compared to adult absorption rates of 10-15%. This makes ingested or dietary lead an

**Table 1: Factors that increase the availability and absorption of ingested lead in children and adults[69]**

| Particle form | pH & solubility | Absorption |
|---|---|---|
| 1. small particle size<br>2. lead adsorption to soil particles<br>3. low soil Pb concentration | 1. fasting (^ pH of stomach)<br>2. Pb species acid solubility<br>3. finely divided soil Pb: more soluble<br>4. large particle soil Pb: less soluble<br>5. $PbC0_3$ & $PbS0_4$: more soluble | 1. non soil Pb form<br>2. Fe, Zn and Cu deficiency<br>3. Ca deficiency plus P deficiency synergism<br>4. Fat (polyunsaturated >saturated fat)<br>5. Low phytate & fibre<br>6. Milk components, |

[65] Jane E. Brody, “Aggressiveness and Delinquency in Boys Is Linked to Lead in Bones,” *The New York Times*, 7 February 1996, p. C9.
[66] Andrew Rubin, “Researcher says poisoning contributed to shooting spree,” *UPI*, 1 August 1986.
[67] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf3.htm
[68] Ibid.
[69] The Health Risk Assessment and Management of Contaminated Sites, 1991, South Australian Health Commission, Adelaide, p 106

| | | |
|---|---|---|
| | | particularly lactose<br>7. Protein deficiency or excess |

exposure source of significant concern to children. Pregnant women may also absorb very high levels of ingested lead, closely approximating the 50% absorption rate of children.[70]

In adults, ingestion may occur during eating, smoking, or nail-biting if one's hands are contaminated, particularly after renovation or hobby activities. Studies of gastrointestinal absorption indicate that although only 10-15% of dietary lead is absorbed normally, this can rise to up to 63% during fasting conditions.[71]

Inhalation is another common means of exposure to lead. The lead exposure of an individual depends roughly upon two factors: the lead levels in the air and the amount of air being inhaled by the individual. Generally adults inhale 15 $m^3$ of air per day while children of two inhale roughly 6 $m^3$ of air per day.[72] Airborne lead levels have fallen steadily since the phase-out of leaded gasoline, but still remain an area of concern in isolated areas.

Today, lead inhalation is of concern mostly to workers in certain lead industries, including mining, smelting, and metal repair or foundry work. Demolition and renovation activities that generate fumes or dusts may also lead to inhalation exposure. Lead particles and fumes may be created by sanding, scraping or burning lead surfaces or by welding and cutting lead or lead-painted objects. Such activities are common in the lead industry and in bridge and building renovation work. Hobby activities that involve melting, burning, cutting or casting lead can also create problematic lead fumes and lead particles.[73]

When lead fumes or particles are inhaled, lead is deposited in the upper and lower respiratory tracts, depending on the particle size. Larger particles are caught higher in the respiratory tract, trapped in the protective mucus lining of the nose, throat and upper respiratory passages. Often this trapped lead is ingested following clearance of the upper respiratory tract. Only lead particles smaller than 1µm in diameter are able to reach the lower respiratory areas. Research has indicated that between 30-50% of inhaled lead is retained by the lungs (varying according to particle size and breathing rates) and thus is available for absorption. More than 90% of lead deposited in the lungs is ultimately absorbed.[74]

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[70] Ibid.
[71] Ibid.
[72] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf3.htm
[73] Ibid.
[74] Ibid.

Skin absorption appears to be a relatively minor source of lead exposure. The ability of the skin to absorb certain organic lead compounds, such as tetraethyl lead, has been recognized for decades, but only recently has laboratory research suggested that inorganic lead compounds (e.g. lead nitrate, lead acetate and lead oxide) can be absorbed through the skin as well. However this absorption occurs only in very small quantities, and poses a threat primarily to workers in the construction trades and paint industry that neglect to wear protective clothing over their skin.[75]

*In utero* lead exposure may occur if the mother is exposed to lead during her pregnancy. The placenta serves as only an imperfect barrier between the mother and fetus, and lead and other heavy metals have been shown to cross the placenta, though in reduced quantities.[76]

Exposure to lead may also occur through the food we eat. Food generally has very low lead levels, but it isn't free of lead altogether. Lead can be taken up by certain crops through the roots; these roots generally contain more lead than the plant stems, leaves, or fruit. Crops grown in soil near homes that have had lead paint deterioration in the past may contain high levels of lead; food grown near heavily-trafficked roads or lead smelting or other industries may also be high in lead. Fields of crops grown in proximity to an industrial source of lead, such as a lead smelter, may accumulate atmospheric lead deposits on stems and foliage.[77]

## Polluted Environments

Apart from unique geological areas where natural lead levels in soil may be elevated, the natural background level of lead in soil worldwide hovers between 10 and 70 parts per million. Soil may become contaminated with lead through industrial pollution, airborne deposition or unsafe disposal practices. Since lead does not dissipate, biodegrade or decay, lead pollution deposited into soil and dust will remain a problem perennially.

Studies of lead contamination in soil have traditionally investigated both heavily trafficked roads and areas where children may play. An Australian study found lead levels of 207 ppm of lead within 2 meters of a heavily traveled road compared to 25 ppm beyond 25 meters.

Another Australian study, conducted in 1992, found that 60% of all play areas sampled in inner-city Sydney were contaminated with lead levels exceeding 300 parts per million; 24% exceeded 1000 parts per million.[78] The study also found that 82% of backyard

[75] Ibid.
[76] U.S. Occupational Safety and Health Administration, "Health Hazard Data" in Appendix A, 29 CFR Sec. 1910.1025.
[77] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf8.htm
[78] Fett M J; Mira M; Smith J; Alperstein G; Causer J; Brokenshire T; Gulson B; Cannata S, "Community Prevalence Survey of Children's Blood Lead Levels and Environmental Lead Contamination in Inner Sydney," *Med J Australia* Oct 1992

residential samples exceeded 300 parts per million and 23% had lead levels above 2500 parts per million. Meanwhile the soil lead levels in the parks and playgrounds of Newcastle, Australia, were found to be similarly high. Over 21% of the 108 samples taken exceeded 300 ppm.[79]

Lead dust is perhaps the least understood and most insidious means of lead exposure. Households often contain lead-bearing dust, whether from disintegrating lead paint, previous renovation activities, or contaminated street dust tracked in by residents and pets.[80] Ceilings, wall voids and floor spaces as well as other housing cavities may harbor lead dust. Lead-bearing household dust can also contaminate soft furnishings (e.g. carpets, lounges, and curtains). Lead dust may also be deposited on rigid surfaces such as footpaths, paved backyards, floors, and street curbs, where it may adhere to feet or shoes and be tracked about.[81]

Fine lead dust particles smaller than 100 µm in diameter are of particular hazard because they adhere more strongly to the skin, they are more soluble in the gastrointestinal tract than coarser particles, and particles less than 10 µm diameter can be readily absorbed through the respiratory tract.[82]

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[79] Devey, Peter, and Li Jingda, "Soil Lead Levels in Parks and Playgrounds: An Environmental Risk Assessment in Newcastle, *Australian Journal of Public Health,* Vol 19, No 2, 1995, pg 191.
[80] New South Wales Environmental Protection Agency website, accessed January 9, 2003. See http://www.epa.nsw.gov.au/leadsafe/leadinf8.htm
[81] Ibid.
[82] Ibid.

# Section Three

## Lead's Impacts on the Environment

Lead contamination and lead dust can have a wide range of impacts on the natural environment. Airborne lead dust has been shown to adversely effect plant growth at concentrations as low as 2-10 $\mu g/m^3$. Lead contamination can also reduce plant species diversity and influence the microbial ecology of bacteria and fungi in the soil. Reduced decomposition and nitrification rates, as well as a reduction in the populations of invertebrates, have also been associated with lead contamination and exposure.[83] Studies conducted in aquatic ecosystems that receive atmospheric lead deposition or industrial or municipal lead effluents have found an increased level of mortality and impaired reproduction in aquatic invertebrates.[84] Lead may also cause blood and neurological changes in fish.[85]

Lead can have fatal consequences for wildlife that mistake lead shot for food or grit and ingest it. Ducks and geese commonly swallow small pieces of stone or gravel to aid digestion and grind up food.[86] When these stones are contaminated with or made of lead, lead poisoning results, often followed by a slow and painful death. "You see them walking with drooping wings and they can't fly," an Illinois veterinarian was reported as saying. "It really is a terrible death because it's very slow and gradual."[87] Other bird species such as songbirds and bald eagles can also be poisoned by ingesting lead shot, either directly or through their prey.[88]

An estimated 1.5 to 2.5 million waterfowl died every year from lead poisoning until 1991, when the U.S. Fish & Wildlife Service banned use of lead shot for hunting them.[89] Lead shot is also now banned for shotgun hunting that occurs near wetlands in national wildlife refuges.[90] However lead shot is still used for other forms of hunting and for target shooting.[91] Nor are these bans universally respected: in 1997 a source in the ammunition industry said that about 20% of American hunters still use lead shot in defiance of the bans.[92] Hence lead shot, both historic and recent, remains in the

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[83] 1999 Annual Air Quality Report for Michigan, p. 23.
[84] *National Air Quality and Emissions Trends Report, 1998*. EPA 454/R-00-003. March 2000. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.
[85] 1999 Annual Air Quality Report for Michigan, p. 23.
[86] Kurt Kleiner, "Good news for ducks," *New Scientist*, August 30, 1997, p. 11.
[87] Jeff Coen, "Ill Birds Reported Near Sportsman's Park," *Chicago Tribune*, 30 July 1999, p. 3
[88] Ted Kerasote, "The sportsman's choice: regular or unleaded? Effect of lead shot on wildlife and measures for preventing it," *Sports Afield*, December 22, 1997, p. 20.
[89] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.
[90] Best Management Practices for Lead at Outdoor Shooting Ranges, Appendix B. USEPA Region 2, December, 2000.
[91] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.
[92] Kurt Kleiner, "Good news for ducks," *New Scientist*, August 30, 1997, p. 11.

environment for wildlife to ingest. As a result, some 300,000 ducks and geese are still poisoned each year by lead shot and bullets.[93]

[93] Ibid.

# Section Four

The History of Lead Regulation

Lead's adverse effects on human health have been known for thousands of years.[94] However lead has only become a public health threat in the last hundred years or so, as it has been integrated into a wide variety of domestic and industrial products. Although federal regulations have since mandated the phase-out of lead from many of these products, including paint, pipes, gasoline, and foodcan solder, these regulations were only issued years or decades after research had indicated the public health threat that lead use posed.[95] Other countries such as Britain, France, the USSR, and Canada were often far ahead of the United States in banning lead use and preventing lead exposure. As a result, the United States today has a higher rate of lead poisoning than any other nation in the industrialized world.[96]

## Lead Paint

Most of the paint used in the early 1900's was based on lead carbonate, commonly known as "white lead". White lead was manufactured by subjecting lead to corrosion, resulting in a fine white powder. After some processing, the powder was sold to paint manufacturers, who mixed it with linseed oil before marketing it for both interior and exterior use. At that time the public felt that "white lead", which could be tinted a variety of colors, was the best protective coating for their homes. Families often used leaded paint not only on their walls, but on their cribs, toys, and furniture as well.[97]

However it quickly became apparent that the use of leaded paint was dangerous to human health. In 1897, Australian researchers identified lead in paint as the cause of a "Toxicity of Habitation," while in 1904, lead paint was identified as a source of childhood lead contamination.[98] The U.S. National Research Council has pointed out that, in 1897, the toxic paint problem was sufficiently well-understood for at least one paint manufacturer in New York City to advertise, "Aspinall's Enamel is NOT made with lead and is non poisonous."[99] The first U.S. case of childhood lead poisoning was diagnosed in 1887;[100] by 1917, U.S. medical authorities had established that childhood lead poisoning was a

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[94] Rachel's Hazardous Waste News #376, February 10, 1994.
[95] The Bartleby online encyclopedia, accessed January 24, 2003. See http://www.bartleby.com/65/le/leadpois.html
[96] Rachel's Hazardous Waste News #376, February 10, 1994.
[97] The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/history_how.html
[98] Rachel's Hazardous Waste News #376, February 10, 1994.
[99] National Research Council, *Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations* (Washington, D.C.: National Academy Press, 1993). Page 25.
[100] The *Democrat and Chronicle* newspaper, accessed January 19, 2003. See http://www.democratandchronicle.com/news/extra/lead/1doctor.shtml

common problem, and the common culprit was leaded paint.[101] “A child,” a medical commentator wrote in 1924, “lives in a lead world.”[102]

In 1909, the threat was conclusive enough for France, Belgium, and Austria to ban the use of interior leaded paint. Tunisia and Greece passed similar legislation in 1922; Czechoslovakia in 1924; Great Britain and Sweden in 1926; Poland in 1927; Spain and Yugoslavia in 1931; and Cuba in 1934.[103] Australia passed a law in curtailing the use of lead in paint manufacture in 1920.[104] During this time the United States remained a notable holdout, and did not fully ban the use of leaded paint until 1978.[105] Indeed, U.S. policymakers actively encouraged the use of leaded paints by requiring their use in public housing projects and other public buildings, including schools, in the 1930’s. It wasn’t until the 1940’s and 1950’s that state and local health agencies begin cautioning the public about the dangers of lead paint, and it wasn’t until 1970 that federal legislation ended the use of lead paint in federally-financed and -subsidized housing.[106]

The result has been a legacy of continued lead pollution, particularly among the poor urban and minority communities that often inhabit old homes. The federal government estimates that leaded paint is still present in some 64 million private homes today.[107] This housing contains an estimated 3 million tons of lead in paint, the equivalent of about 140 pounds of lead per household, or 63 billion micrograms of lead per household.[108] Unless removed, leaded paint will inevitably disintegrate into household dust and slowly poison household inhabitants. According to the US Public Health Service, the health costs associated with this continued exposure are measured in billions of dollars.[109]

## Lead Pipes

Lead pipes were used for the delivery and transport of water in the United States long after copper and PVC piping became widely available. Even after copper piping became more common, lead solder and flux were often used to join the pipes. This lead solder, which was used on water pipes throughout the United States, may be the major cause of lead contamination in drinking water today. The United States didn’t enact a nationwide

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[101] The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/history_how.html
[102] Ibid.
[103] The *Democrat and Chronicle* newspaper, accessed January 19, 2003. See http://www.democratandchronicle.com/news/extra/lead/1doctor.shtml
[104] The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/history_how.html
[105] The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/thelaw_legislation.html
[106] The *Democrat and Chronicle* newspaper, accessed January 19, 2003. See http://www.democratandchronicle.com/news/extra/lead/1doctor.shtml
[107] The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/thelaw_legislation.html
[108] Rachel’s Hazardous Waste News #376, February 10, 1994.
[109] Jamie Lincoln Kitman, “The Secret History of Lead.” *The Nation,* 20 March 2000. Available at: http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.

ban on the use of lead piping and solder until 1986, decades after research had first suggested that lead was leaching into water supplies.[110] The ban was legislated as an amendment to the Safe Drinking Water Act (SDWA) of 1974, and mandated that all pipes, solders, pipe fittings or plumbing fixtures used in the installation or repair of any facility which provided water for human consumption had to be "lead-free."[111] However the ban came too late for many homes, which continue to use lead piping today, often unwittingly. Lead piping also still connects some homes to public water supplies.[112]

## Lead Solder in Foodcans

Lead solder was once used widely to seal the side seams of food cans. Although this solder was applied to the outside of the can, some of the solder bled through the ends of the side seam. This created a strong, leakproof can, but it also contaminated the food it contained with trace quantities of lead, particularly if the food was acidic. Lead solder contributed nearly all of the lead found in canned foodstuffs.[113] As late as 1979, fully 90 percent of canned foods were packaged in lead-soldered containers.[114] However over the last few decades, as research indicated even low levels of exposure could lead to irreversible health effects, it became increasingly clear that lead solder use in food cans posed a public health threat. U.S. manufacturers judged the threat to be so grave that they voluntarily phased out the use of leaded solder in food cans in advance of any federal regulation, completing the process by 1991.[115] Fully 99% of the Canadian food industry used alternatives to lead solder by the early 1990s, and nearly two dozen countries worldwide had banned its use completely.[116] Although many countries continued to use lead solder, and export these cans to the United States for consumption, it wasn't until 1995 that the FDA finally concluded that lead solder should be banned from all food cans sold in the United States.[117]

## Leaded Gasoline

In 1921, a General Motors employee discovered that adding a small amount of tetraethyl lead to gasoline eliminated engine knock and improved performance and efficiency.[118] Shortly afterwards, in December 1922, H.S. Cumming, the US Surgeon General, wrote, "Inasmuch as it is understood that when employed in gasoline engines, this substance will add a finely divided and nondiffusible form of lead to exhaust gases, and furthermore, since lead poisoning in human beings is of the cumulative type resulting frequently from

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[110] The University of Georgia website, accessed December 14, 2002. See http://www.ces.uga.edu/pubcd/c819-14w.html
[111] http://environment.copper.org/SDWA_intro.html
[112] The University of Georgia website, accessed December 14, 2002. See http://www.ces.uga.edu/pubcd/c819-14w.html
[113] The Food and Drug Administration website, accessed on January 17, 2003. See http://www.fda.gov/bbs/topics/NEWS/NEW00416.html
[114] Ibid.
[115] Ibid.
[116] Ibid.
[117] The Food and Drug Administration website, accessed on January 17, 2003. See http://www.fda.gov/ora/fiars/ora_import_ia9912.html
[118] Nickerson SP. 1954. Tetraethyl lead: a product of American research. *J. Chem. Educ.* 31:560-71

the daily intake of minute quantities, it seems pertinent to inquire whether there might not be a decided health hazard associated with the extensive use of lead tetraethyl in engines."[119] One Yale University physiologist echoed this concern, warning in 1923 that leaded gasoline would create poisonous leaded dust that would infuse U.S. cities.[120] Despite these concerns, leaded gasoline went into production, was used widely in the United States, and soon became the dominant form of gasoline on the world market.[121] This gasoline typically had 4 grams of lead/gallon, and created leaded dust when burned.[122] Between 1920 and 1970, approximately 7 million tons of lead were burned in gasoline;[123] 172,380 tons were burned in 1970, accounting for fully 78% of all airborne lead emissions.[124] The resultant lead dust was often inhaled, or if not, ingested; lead fallout contaminated soil and dust, food crops and pasture land.[125]

Exposure to this gasoline lead varied, depending on local traffic patterns, diets, food sources, and personal habits. However the public health implications of this exposure became clear after series of epidemiological studies found lead particulate emissions from motor vehicles presented a significant harm to urban populations, particularly children.[126] Between 1927 and 1987, as many as 68 million children may have suffered from toxic lead exposures due to its use in gasoline.[127]

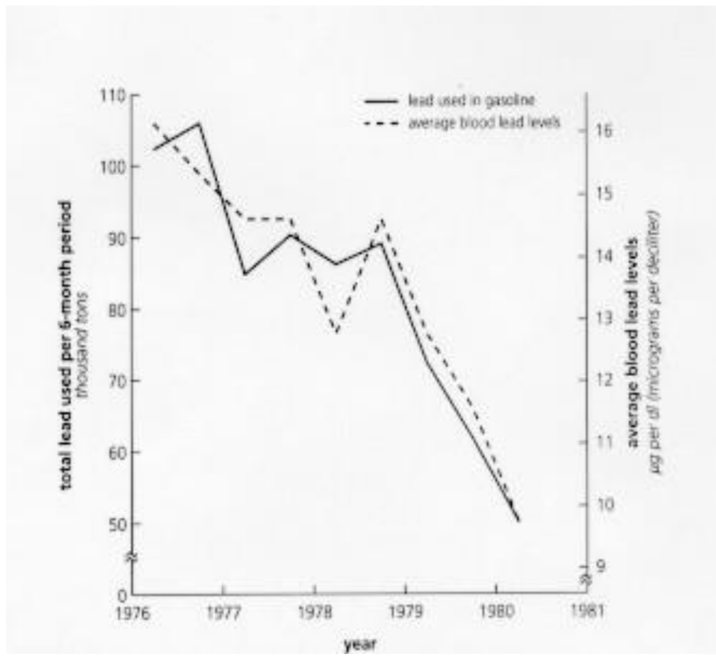


**Figure 2: Decreases in blood lead values and amounts of lead used in gasoline from 1976 to 1980.**
Source: Agency for Toxic Substances Disease Registry, 1988. The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress. Atlanta: ATSDR.

119 Jamie Lincoln Kitman, "The Secret
http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.
120 The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/history_how.html
121 Nriagu JO. 1990. "The Rise and Fall of Leaded Gasoline." *Sci. Total Environ.* 921: 13-28
122 1999 Annual Air Quality Report for Michigan, p. 23.
123 The Lead Poisoning Resource Center website, accessed October 12, 2002. See http://www.aboutlead.com/history_how.html
124 EPA Office of Air and Radiation website. http://www.epa.gov/oar/urbanair/lead/what.html. Last updated February 12, 2001. Accessed April 24, 2001.
125 V. M. Thomas, "The Elimination of Lead in Gasoline." *Annual Review of Energy and the Environment* 1995. 20:301-324.
126 "Prohibition on Gasoline Containing Lead or Lead Additives for Highway Use". 61 FR 3832, February 2, 1996.
127 Jamie Lincoln Kitman, "The Secret History of Lead." *The Nation,* 20 March 2000. Available at: http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.

The Soviet Union was the first country to restrict the use of lead in gasoline: by 1967, the sale of leaded gasoline was banned in many of the country's major cities and tourist areas.[128] However the use of leaded gasoline was unrestricted elsewhere, and it has continued until the present day. Japan began reducing the quantity of lead in gasoline in the 1970s, after high blood lead concentrations were reported in Tokyo.[129] Leaded gasoline was also eliminated in Antigua, Austria, Brazil, Canada, Colombia, South Korea, Suriname, and Sweden.[130]

However several years of bitter wrangling had gone by before the EPA decided to regulate lead use in gasoline. Despite the fact that unleaded gasoline cost only $0.01 more per liter to produce,[131] a proposed phase-out met with fierce opposition, and the EPA was only half-hearted in its intent. A full phase-out began in 1976, but EPA Administrator Ann Gorsuch called for a reintroduction as late as 1982.[132] However the public health benefits of the phase out were already growing apparent. Average blood lead levels in the United States fell in tandem with the use of leaded gasoline, declining from 16 μg/dL in 1976 to 3 μg/dL in 1990.[133] The decline was most striking among children: between 1970 and 1987, the blood lead levels of up to two million children per year were reduced below the

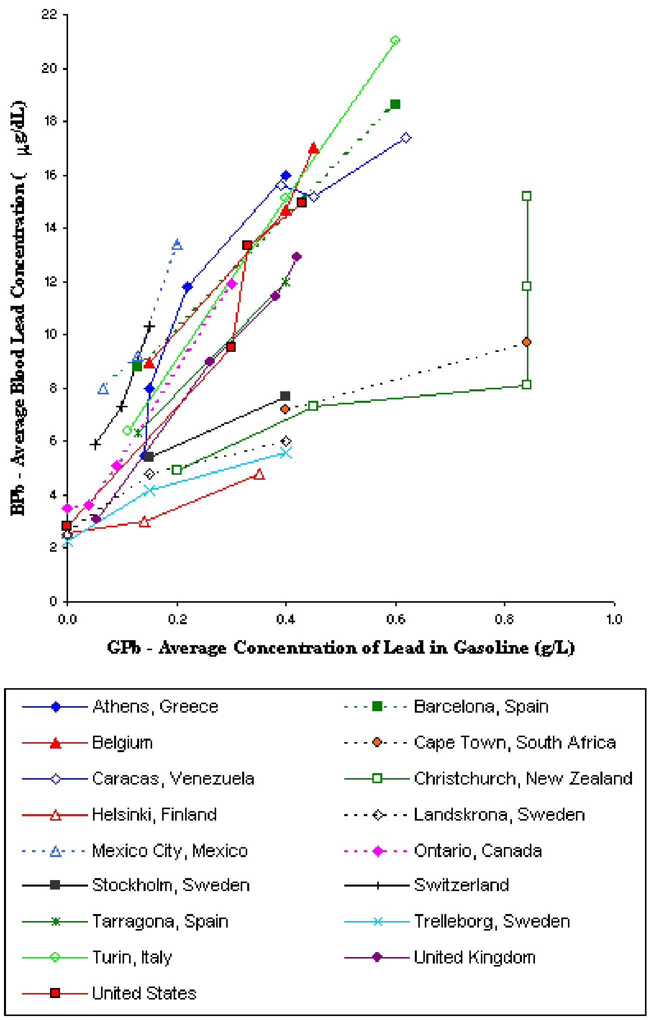


**Figure 3: Blood lead level correlations with the use of leaded gasoline.**
Source: Thomas et al. "Effects of Reducing Lead in Gasoline," *Environmental Science and Technology* 33(22):3942-3947, 1999

[128] Danielson L. 197 "Gasoline Containing Lead." *Ecol. Res. Comm. Bull. No. 6*, 45 pp.
[129] Japan Environmental Agency. 1988. *Motor Vehicle Pollution in Japan*. Tokyo: Automotive Pollution Control Division, Air Quality Bureau. 3rd ed.
[130] V. M. Thomas, "The Elimination of Lead in Gasoline." *Annual Review of Energy and the Environment* 1995. 20:301-324.
[131] Ibid.
[132] Jamie Lincoln Kitman, "The Secret History of Lead." *The Nation*, 20 March 2000. Available at: http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.
[133] V. M. Thomas, "The Elimination of Lead in Gasoline." *Annual Review of Energy and the Environment* 1995. 20:301-324.

threshold of concern.[134] A similar decline was observed in the United Kingdom: a 50% reduction in leaded gasoline use[135] resulted in a 20% reduction in blood lead levels.[136] One EPA study, completed in 1985, found that as many as 5,000 Americans may have died annually from lead-related heart disease due to the inhalation of lead from gasoline.[137]

Thankfully, leaded gasoline no longer poses a significant threat to public health. Lead levels in gasoline were reduced to 0.05 gram/gallon in 1996;[138] as a result, airborne lead emissions from vehicle usage today contributes less than 1% of all national emissions.[139] Ambient lead air pollution monitoring by the nation's roadways has revealed a decrease of 97% since the phase-out of gasoline began.[140] Since 1995 the average national airborne lead level, measured across 189 monitoring sites, has remained at 0.04 $\mu g/m^3$.[141] Only five counties exceeded National Ambient Air Quality Standards for lead (an average level of 1.5 µg/m3 per calendar year) in 1998, comprising a population of less than 4.3 million people.[142]

Although the elimination of leaded gasoline is hailed today as a public health triumph, it was nearly rescinded in 1982. The fact that it occurred at all is less a testament to the diligence of the EPA than to the indisputable and overwhelming evidence of the threat that lead use posed. Unfortunately, this pattern has been repeated over and over and over again. Too often, federal lead regulation is a case of 'too little, too late'

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[134] Jamie Lincoln Kitman, "The Secret History of Lead." *The Nation*, 20 March 2000. Available at: http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.
[135] Jones KC, Symon C, Taylor PJL, Walsh J, Johnston AE. 1991. "Evidence for a Decline in Rural Herbage Lead Levels in the U.K." *Atmos. Environ. A* 25:361-69
[136] Larbey RJ. 1994. "Issues Surrounding the Use of Lead in Gasoline—Energy, Economic and Environmental." *Sci. Total Environ*. 146/147:19-26
[137] Jamie Lincoln Kitman, "The Secret History of Lead." *The Nation*, 20 March 2000. Available at: http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.
[138] V. M. Thomas, "The Elimination of Lead in Gasoline." *Annual Review of Energy and the Environment* 1995. 20:301-324.
[139] "Ambient Air Quality Surveillance for Lead—Final Rule", 64 FR 3030, January 20, 1999.
[140] Ibid.
[141] *National Air Quality and Emissions Trend Report, 1998*. EPA 454/R-00-003. March, 2000. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.
[142] Ibid.

# Section Five

## Producer Responsibility

The Producer Responsibility concept has been around for several decades. It stems both from the desire to create an environmentally sustainable society, and the understanding that the consumer cannot create this society on their own. More than a billion people do not have the purchasing power to influence producer decisions and are forced to accept whatever is available.[143] Those people that do possess significant purchasing power are often unable to wield it constructively, as they are unaware of the environmental, economic, and social ramifications of their purchasing decisions. Even those consumers that research these ramifications may find that the information is inaccessible or unavailable. Thus, the individual consumer is often poorly positioned to wield their purchasing power sustainably.

This is a powerful indictment of market forces, suggesting that the market, left on its own, would be unable to internalize the environmental and social ramifications of its products and production practices. Clearly some external guidance is needed, and this has historically been supplied through governmental regulation. However, as has just been demonstrated in the preceding section, traditional command-and-control regulation is not entirely up to the task.

This is a decades-old problem, but today, a new solution is presenting itself: Producer Responsibility. Several definitions exist for the concept, but a general definition can be given as follows: *"Producer Responsibility is a principle which places responsibility for the environmental impact of a product onto the producers of that product. It is increasingly being used as a mechanism for environmental protection in countries throughout the world. Producer Responsibility is intended to address "cradle-to-grave" environmental problems, from the initial minimization of resource use, through the extended product life span, to the recovery and recycling of products once they have been disposed of as waste."*[144]

Producer Responsibility is a relatively new idea in policy thinking. The concept stresses that the ultimate responsibility for the ramifications of a particular product should rest with its producer, instead of its consumer. As early as 1975, the Swedish Government stated: "The responsibility, that the waste generated during the production processes could be taken care of in a proper way, from an environmental and resource-saving point of view, should primarily be of the manufacturer. Before the manufacturing of a product is commenced it should be known, how the waste which is a result of the production

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[143] Consumer Unity and Trust Society website, accessed December 2, 2002. See http://cuts.org/viewpnt-Extended.htm
[144] Scottish Environmental Protection Agency website, accessed November 28, 2002. See http://www.electronics-scotland.com/environment/Environment_article.cfm?EnvironmentID=6

process should be treated, as well as how the product should be taken care of when discarded."[145]

This reevaluation of product responsibility promises to internalize the environmental and health impacts of many products and manufacturing processes. The manufacturer of a product is uniquely able to address these impacts through product design, a role that neither the government nor consumers can efficiently play. Products can be made out of recycled materials, and designed for easy recyclability; if a particular material is hazardous, another can be substituted. In this way, products can be made in harmony with environmental processes, and their environmental impacts can be averted.

## Producer Responsibility Regulations

A number of countries around the world have taken the Producer Responsibility concept and used it to fashion a variety of innovative and effective environmental legislation. This legislation codifies the central theme of producer responsibility: *that the manufacturer, and not the consumer or the government, is ultimately responsible for the impacts of its product.* The physical and economic responsibilities that Producer Responsibility regulations often put in place create a strong incentive for manufacturers to improve the environmental performance of a product throughout its life-cycle. In addition, by emphasizing the role of the manufacturer, Producer Responsibility has the potential to work better in a market economy than previous environmental protection strategies, which have focused primarily upon the role of the governments and regulatory authorities.[146]

The 1985 Swedish Law on Chemical Products was one of the first laws to put the concept into practice, stating that the producer must substitute, whenever possible, hazardous substances with less hazardous or harmless ones.[147] Germany began to regulate producer responsibility in 1991, when its Packaging Ordinance shifted the responsibility for packaging waste recycling and disposal—comprising one-third of the municipal waste stream—from local governments to private industry.[148] Today its automotive regulations, mandating 85% recyclable content by design, are among the most advanced in the world.[149] Sweden has also legislated producer responsibilities for its automotive industry,[150] and Finland has incorporated the concept into its beverage container

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[145] "Återvinning och avfall" (Recycling and Waste Management), Government bill 1975:32, Stockholm 1975

[146] "Extended Producer Responsibility as a Strategy to Promote Cleaner Production," Proceedings of an invitational expert seminar, Trolleholm Castle, Sweden, 4-5 May 1992. See http://www.lu.se/IIIEE/research/products/epr/epr_seminar_1992/epr_1992_lindhqvist.html

[147] Ibid.

[148] Consumer Unity and Trust Society website, accessed December 2, 2002. See http://cuts.org/viewpnt-Extended.htm

[149] *Industry Week*, March 1st, 2002. See http://www.industryweek.com/CurrentArticles/asp/articles.asp?ArticleID=1205

[150] Mats Magnell & Erik Rydén "The Swedish Car Scrapping System" in proceedings of seminar "Cleaner Production Strategies for the Automotive Sector" arranged in the framework of the UNEP IE/PAC Cleaner Production Programme, Lund 1992.

collection programs.[151] Japan has also applied the concept to its packaging industry, beginning in 1995, and the Japanese government has supported the Producer Responsibility concept through the Organization of Economic Cooperation and Development (OECD).[152] In the European Union, current draft and adopted Producer Responsibility Directives are being implemented widely in such areas as packaging, end-of-life vehicles, electrical and electronic equipment, batteries and tires.[153]

The implementation of Producer Responsibility concepts often varies by country and by the products being targeted. Germany shifted full responsibility for packaging waste to industry, whereas in Japan and France the government and private industry share this responsibility.[154] However it may be implemented, manufacturers always bear responsibility for the environmental and health impacts of their products, according to the Producer Responsibility doctrine, even in the absence of governmental oversight and public outrage. The highest corporate responsibility is to serve the public interest; this responsibility must guide corporate decision-making, not the presence or absence of governmental regulation. Although our economic system may not reward corporate "good citizens" properly, this serves as little excuse for bad corporate behavior. Enforcement mechanisms will always be advisable, but will never be sufficient. Truly sustainable behavior must begin with the producers and manufacturers, themselves, and no one else.

[151] Both the German and the Finnish developments are described in the proceedings of the seminar "Packaging and the Environment - policies, strategies and instruments" arranged in the framework of the UNEP IE/PAC Cleaner Production Programme, Lund 1991.
[152] Consumer Unity and Trust Society website, accessed December 2, 2002. See http://cuts.org/viewpnt-Extended.htm
[153] Ibid.
[154] Ibid.

# Section Six
## Lead Use in Ammunition

Lead pollution due to lead use in bullets and shot is both serious and pervasive. Lead contamination is common at both indoor and outdoor firing ranges; lead pollution due to firearm use outside of these ranges is impossible to quantify but certainly tugs at the imagination. No records on lead ammunition production are kept in the United States, but it has been estimated that between 400 and 600 tons of lead are used each day to make bullets and shot.[155] A high proportion of this lead is left behind at shooting ranges; the rest, presumably, is left scattered throughout the environment.[156]

Indoor ranges are primarily used for firing handguns or lower-caliber rifles, shooting at relatively close range. Indoor ranges have been identified as a potent source of human lead exposure, particularly for those who work there or use the range often. Outdoor ranges can be used for a variety of target shooting, using every conceivable type of gun. These ranges pose less of a threat of human lead exposure, but pose a much greater threat of environmental lead contamination. Lawsuits and regulatory action have already forced several shooting ranges to close because of the dangers that they pose to human health and the environment.[157]

## Indoor Firing

There are more than 4,000 indoor firing ranges in the United States today, nearly all of which use lead shot exclusively.[158] The California Department of Health Services reported in 1993 and 1994 that, among commercial industries, the greatest number of lead poisoning cases were associated with indoor firing ranges.[159] Lead exposure and contamination has been reported regularly at law enforcement firing ranges[160] and firing ranges located within school buildings. Although indoor firing ranges pose significant threats to human health, most privately operated firing ranges are completely unregulated by public health authorities.[161]

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155 Jonathan Beard, "Fill 'em full of tungsten," *New Scientist*, December 2, 1995, p. 25.
156 North American Hunting Club, *National Shooting Range Symposium: Proceedings* (1993), p. 146.
157 North American Hunting Club, *National Shooting Range Symposium: Proceedings* (1993), p. 73.
158 "Officials Investigating Gun Ranges for Lead Poisoning," *Associated Press*, October 29, 2002. Available at http://www.galleryofguns.com/shootingtimes/articles/DisplayArticles.asp?ID=3360.
159 California Department of Health Services, Occupational Lead Poisoning Prevention Program, *Blood Lead Levels in California Workers: 1993-1994* (September 1997), p. 21.
160 "Lead Health Hazard Evaluation: FBI Academy, Quantico, Virginia," HETA 91-0346-2572 (April 1996), and "NIOSH Health Hazard Evaluation Report: Dartmouth Police Department," HETA 96-0107-2613 (December 1996).
161 Michigan State University, Department of Medicine, Division of Occupational and Environmental Medicine, *2001 Annual Report on Blood Lead Levels in Michigan*, November 2001, Available at http://web2.chm.msu.edu/oem/Lead/01LeadAnnualReport_ALL.pdf.

Lead exposure in indoor firing ranges typically results from the inhalation of lead dust and particles suspended in the air. These particles are produced through the ignition of the primer, which contains lead styphnate; the bullet's passage through the gun barrel, which scrapes microscopic lead particles from the shot; and the impact of the bullet with the target or the backstop behind the target, which creates additional lead fragments and dust.[162] Lead exposure may occur as a result of shooting, the handling spent casings, the cleaning bullet traps, or firearm cleaning.[163]

The risk of lead poisoning associated with indoor shooting ranges has been known since the mid-1970s, and has been documented in a number of studies conducted by public health authorities.[164] According to one NRA official, "Lead contamination directly contributed to closing hundreds of indoor ranges in the last 20 years."[165] Of the 825 adults in Michigan who tested positive for lead poisoning in 2001, 100—or fully 12%—received their exposure at indoor firing ranges (3% as part of work and 9% as a hobby).[166] One gun range safety instructor that suffers from blood lead levels 20 times the safety standard was reported in *The Detroit News* as saying, "I dedicate my life to safety and the gun range probably will end my life sooner."[167]

Unfortunately, lead poisoning from firing range exposure is fairly widespread. In one instance, a pregnant woman in her early 30's approached her doctor and reported suffering from headaches, abdominal pain, memory loss, fatigue, irritability, muscle weakness, and other symptoms. Testing revealed that her blood lead level was 28 µg/dL; her baby's blood lead was 7 µg/dL at birth. The source of this contamination was traced to the firing range where she had worked over the course of three years. Air lead

[162] Sarah E. Valway et al., "Lead Absorption in Indoor Firing Range Users," *American Journal of Public Health* 79 (August 1989): 1029.
[163] Commonwealth of Massachusetts, Department of Labor and Workforce Development, Division of Occupational Safety, *Firing Ranges: The Airborne Lead Hazard*, available at www.magnet.state.ma.us/dos/leaddocs/ Lead-firing.htm.
[164] Three of the earliest were: Philip J. Landrigan et al., "Chronic Lead Absorption: Result of Poor Ventilation in an Indoor Pistol Range," *Journal of the American Medical Association* 234, no. 4 (1975): 394; Thomas L. Anania and Joseph A. Seta, *Lead Exposure and Design Considerations for Indoor Firing Ranges* (Washington, DC: National Institute for Occupational Safety and Health, 1975); Karl E. Anderson et al., "Plumbism from Airborne Lead in a Firing Range," *The American Journal of Medicine* 63 (August 1977): 306. See also *Appendix Alpha*.
[165] International Association of Fish and Wildlife Agencies, *Proceedings of the First National Shooting Range Symposium* (1990), p. 91.
[166] Michigan State University, Department of Medicine, Division of Occupational and Environmental Medicine, *2001 Annual Report on Blood Lead Levels in Michigan*, November 2001, Available at http://web2.chm.msu.edu/oem/Lead/01LeadAnnualReport_ALL.pdf.
[167] "Officials Investigating Gun Ranges for Lead Poisoning," *Associated Press*, October 29, 2002. Available at http://www.galleryofguns.com/shootingtimes/articles/DisplayArticles.asp?ID=3360.

levels at the range were above the occupational standard of 50 $\mu g/m^3$; the range provided no protective clothing, did not educate its employees about the threat of lead, and neglected to properly dispose of accumulated lead dust.[168]

Direct participants such as firearm instructors, range employees, and individual shooters—those with the greatest and most consistent exposure to the airborne lead—bear the greatest risk of lead contamination.[169] Most often this risk is associated with chronic exposure to lead contamination; however, several acute cases of lead poisoning at firing ranges have been reported. In one instance, a police firearms instructor suffered acute respiratory failure and died in his sleep after he was exposed to high levels of ambient lead at a five-day firing range training course.[170] The lungs of a New Hampshire firing range employee were also severely damaged after a single day's intensive exposure to lead contaminants. The employee was diagnosed with a chronic lung disease after cleaning out lead dust deposits, wearing only a painter's mask for protection.[171]

Firing range maintenance employees are at a particularly acute risk of lead exposure if the proper protective measures are not taken. One of the highest blood lead levels ever recorded by the Baltimore City Health Department was found in an attendant who regularly cleaned an amusement park shooting gallery.[172] One 17-year old worker at an indoor firing range reported a battery of health effects, including vomiting, severe abdominal pain, and constipation, after five months of employment.[173] Unfortunately, many employees of firing ranges are often unaware of the severity of the risks they face, and are either not provided with the proper protective equipment or chose not to wear it.

Ordinary users of indoor firing ranges are also at risk of lead exposure, particularly if they frequent the ranges often or for long period of time. Officials at the California Occupational Lead Poisoning Prevention Program have pointed out this risk, reporting that elevated blood lead levels are common among recreational and competitive shooters.[174] In 1999, a doctor at Children's Hospital in Boston reported that four adolescent girls, all competitive shooters at an indoor firing range, suffered from

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[168] Michigan State University, Department of Medicine, Division of Occupational and Environmental Medicine, *2001 Annual Report on Blood Lead Levels in Michigan*, November 2001, Available at http://web2.chm.msu.edu/oem/Lead/01LeadAnnualReport_ALL.pdf.

[169] Second Amendment Foundation News Release, "New Lead Recycling System Helps School Reclaim Range," January 10, 1998, available at: www.saf.org/pub/rkba/hindsight/rec.html

[170] Shawne K. Wickham, "Danger on the Range: Lead Dust and Gases," *New Hampshire Sunday News*, 20 February 1994, p. A1.

[171] "Shooting Range Worker Given Another Chance To Pursue Workers' Comp Claim," *Mealey's Litigation Reports* 5, no. 7 (1996).

[172] Richard J. Sagall, "Shooting for lead poisoning; contaminated air in indoor shooting ranges," *Pediatrics for Parents*, October 9, 1988, 5.

[173] Karl E. Anderson et al., "Plumbism from Airborne Lead in a Firing Range," *The American Journal of Medicine* 63 (August 1977): 306.

[174] Letter to Tom Diaz from Barbara Materna, Chief, Occupational Lead Poisoning Prevention Program, Occupational Health Branch, Department of Health Services (May 30, 2000).

abnormally high blood lead levels.[175] And three out of four regular shooters at a Manchester, United Kingdom, range had blood lead levels so high that had they been obtained occupationally, monitoring would have been required by law.[176]

One study, conducted by Colorado public health officials, investigated the lead exposure of 17 law enforcement trainees during and after a three-month period of firearm instruction at a state-owned indoor range. Airborne lead levels in the range were found to exceed federal Occupational Safety and Health Administration (OSHA) safety standards 40 times over, despite the fact that a new ventilation system had been installed early in the study. Although none of the 17 members of the firearm class were reported as having elevated blood lead levels before their training, fully 15 had elevated levels after taking the course. Eight of these students had blood lead levels so high that OSHA regulations required medical monitoring. The Colorado study concluded that "frequent users would be at risk for developing elevated blood lead levels and adverse health effects from the lead exposure."[177]

The lead exposure risk from indoor firing ranges extends beyond those who actually use them. The families of shooting range employees or users may also be exposed, as lead dust that has settled on clothing, shoes, and accessories worn or used at the range is brought into the home.[178] This "take-home" lead exposure can cause secondary lead poisoning, endangering family members, including children.[179] According to a New Hampshire police captain and range instructor, an activity as common as doing the laundry can pose a health risk after time at a firing range: "If you take your clothing home, you actually contaminate the family clothing when you wash it [together]," he said.[180] Officials in California reported that "some serious lead poisoning cases among construction employees engaged in demolition of a firing range" had led to contamination as well "among these employees' children."[181] And a 1996 study by the National Institute of Occupational Safety and Health (NIOSH) studied "take-home" lead exposure and found that students with the FBI Academy's Firearms Training Unit had much higher levels of lead in the carpets of their dormitory rooms than non-students. This led NIOSH to report that, "FBI students may be contaminating their living quarters with lead," and

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[175] "Lead Poisoning in Adolescents Who Are Competitive Marksmen," letter to the editor from Michael Shannon, MD, MPH, *The New England Journal of Medicine* 341, no. 11 (1999).
[176] "Firing Ranges 'A Lead Hazard,'" *The Guardian (London)*, 1 April 1994, p.6.
[177] Sarah E. Valway et al., "Lead Absorption in Indoor Firing Range Users," *American Journal of Public Health* 79, no. 8 (1989): 1032.
[178] California Department of Health Services, *Don't take lead home from your job!*, downloaded May 24, 2000, from www.ohb.org/leadhome.htm
[179] Richard J. Sagall, "Shooting for lead poisoning; contaminated air in indoor shooting ranges," *Pediatrics for Parents*, October 9, 1988, p. 5.
[180] Shawne K. Wickham, "Danger on the Range: Lead Dust and Gases," *New Hampshire Sunday News*, 20 February 1994, p. A1.
[181] Letter to Tom Diaz from Barbara Materna, Chief, Occupational Lead Poisoning Prevention Program, Occupational Health Branch, Department of Health Services (May 30, 2000).

that "a potential problem of 'take-home' lead exposure of families of firearms instructors was found."[182]

Those who work or spend time in buildings that house firing ranges may be contaminated by the resultant lead dust unless particular precautions are taken, including the isolation of the range's ventilation system and the creation of a negative air pressure in the range so that lead dust does not escape.[183] Even decommissioned ranges may still pose a threat, as lead dust has been found in building air ducts long after ranges have been retired.[184] Ventilation systems may help protect the employees and users of a range, but they can also endanger the health of those outside the range. One day-care center in Clearwater, Florida, was closed and its children tested for lead exposure after it became clear that the indoor shooting range next door was venting lead-contaminated air into the children's playground area. Testing revealed that airborne lead levels just outside the range's exhaust fan were 8,000 times higher than the county's health standard, and that lead levels in the soil near the daycare center were 40 times the acceptable standard.[185]

Obviously these ranges pose a particularly dangerous threat to children when they're located within existing schools. Although the exact number of these ranges is unknown, several have been shut down due to health concerns in recent years.[186] Six were closed in Lancaster County, Pennsylvania, after elevated blood lead levels were discovered in students that commonly used the indoor ranges.[187] Air testing conducted at an elementary school in Lynbrook, New York, revealed that the indoor shooting range in the school's basement was a serious source of lead contamination, to the surprise of the school's superintendent. "I got the results and was shocked," he said. "I made the decision to close the school, shut down the range and begin the cleanup."[188] State officials subsequently advised all schools with indoor ranges to conduct airborne lead testing, and two other schools with firing ranges were temporarily closed as a result.[189] School ranges can still pose a health threat to children long after they have been shut down.[190] One school rifle range in the Louisville, Kentucky, school system posed a lead contamination threat even though it had been decommissioned years earlier.[191]

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[182] National Institute for Occupational Safety and Health, "Lead Health Hazard Evaluation: FBI Academy, Quantico, Virginia," HETA 91-0346-2572 (April 1996).
[183] Brian O'Rourke, "Indoor firing range ventilation system," *Heating, Piping, Air Conditioning*, October 1992, p. 77.
[184] Ralph R. Ortega, "Powder in town hall duct was lead, tests indicate," *Asbury Park Press* (Neptune, NJ), 27 March 1998, p. 2.
[185] Sue Landry, "Children tested for lead," *St. Petersburg Times*, 7 January 1992, p. 1.
[186] Frank Eltman, "School rifle teams in spotlight amid spate of school shootings," *The Associated Press State & Local Wire*, 22 November 1999.
[187] Civia Katz, "Exposure to lead silences rifle teams: Students at Manheim Twp., other schools have high lead levels," *Intelligencer Journal* (Lancaster, Pa.), 20 November 1999, p. A1.
[188] John T. McQuiston, "Lead Detected in Rifle Range Brings Closing of L.I. School," *New York Times*, 12 November 1999, p. B6.
[189] "Hazard Tests urged at School Rifle Ranges," *New York Times*, 16 November 1999, p. B8.
[190] Megan O'Matz, "Disarming Tradition; Schools' Rifle Teams Come Under Scrutiny," *Chicago Tribune*, 5 November 1999, p. 1.
[191] Stephanie Raphael, "Get the lead out!" *Business First-Louisville*, 11 April 1994, p. 37.

The threat that lead shot use at indoor ranges poses to human health is both severe and preventable. Proper safety precautions can reduce the risk, but can only go so far. As long as lead ammunition is used, lead dust will continue to be created, and will pose a health threat to those who work at, use, clean, reside near, or go to school in the same buildings as these ranges.

## Outdoor Firing

Lead shot also poses a threat when used outdoors, although the danger is primarily environmental. Lead bullets and shot fired outdoors can contaminate ground water, poison wells and other water sources, harm wetlands and waterways, and poison wildlife, particularly waterfowl that often ingest lead pellets.[192] Lead pollution often occurs at outdoor firing ranges when shotgun pellets and rifle bullets are fired into backstops or out over waterways.[193] "The quantity of recreational lead deposited in the environment is enormous," writes Ted Kerasote in *Sports Afield*. "For example, at some trap and skeet ranges, lead shot densities of 1.5 billion pellets per acre have been recorded. That's 334 pellets in every square foot."[194]

High densities of lead shot and bullets have also been found at hunting sites across the United States, Canada, and Great Britain. In 1959, one researcher reported that an average of 28,277 spent lead pellets per acre were found at 24 different sites in 7 states and provinces.[195] A similar study in Great Britain, conducted in 1984, found that lead pellets had been deposited on 22 different sites at a rate varying from 2.04 pellets to 30.0 pellets per square meter.[196]

## Impacts on Wildlife

Spent lead pellets are often ingested by waterfowl during feeding.[197] Several studies have found that ducks captured in areas subjected to intensive hunting and shooting had a significantly higher rate of pellet ingestion than ducks from other areas. In 1959, a researcher found that 7.3 percent of 3,900 blue-winged teal captured in hunting areas had

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[192] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.

[193] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.

[194] Ted Kerasote, "The sportsman's choice: regular or unleaded? Effect of lead shot on wildlife and measures for preventing it," *Sports Afield*, December 22, 1997, p. 20.

[195] Bellrose, F.C. 1959. "Lead Poisoning As A Mortality Factor in Waterfowl Populations." *Illinois Natural History Survey Bulletin* 27(3):235-288.

[196] Mudge, G.P. 1984. "Densities and settlement rates of spent shotgun pellets in British wetland soils." Environmental Pollution (Series B) 8 (1984): 299-318.

[197] Sanderson, Glen C. and Frank C. Bellrose. 1986. "A Review of the Problem of Lead Poisoning in Waterfowl." *Illinois Natural History Survey*, Champaign, Illinois. Special Publication 4. 34pp. Jamestown ND: Northern Prairie Wildlife Research Center Home Page. Available at: http://www.npwrc.usgs.gov/resource/othrdata/pbpoison/pbpoison.htm.

swallowed lead pellets, an incidence far higher than that of the country at large.[198] Although only 1.6 percent of wood ducks throughout the United States have been found with lead pellets in their gizzards, fully 9.4 percent of 941 birds captured in intensive hunting areas had shot in their stomachs.[199] A 1951 study found that the number of ducks with lead pellets in their gizzards increased fourfold during the hunting season. Before the hunting season began, 3-4 percent of the ducks examined had bullets in their gizzards, but this number increased steadily to 12 percent at the end of the hunting season.[200]

Waterfowl in nearly every region of the United States and Canada have been found with lead pellets in their bellies.[201] A compilation of studies conducted between 1973 and 1984 found that fully 8.9 percent of 171,697 duck gizzards analyzed contained lead shot and pellets (See Appendix Beta). However this number isn't representative of the number of ducks and geese that actually consume lead pellets in a given year. Lead shot typically disappears from a duck's gizzard within twenty days—either because it has passed through, or because it has been eroded into smaller particles. Thus, the number of waterfowl found to contain lead pellets at any one time is only indicative of recent ingestion. This led researchers with the Northern Prairie Wildlife Research Center to conclude that "as much as 40 percent of the waterfowl population ingests lead shot during a single season of exposure."[202]

A variety of factors may influence the rate at which lead pellets are consumed. Feeding habits, the depth of the water, the presence of ice cover, season, and the firmness of the lake or river bottom all vary the rate at which waterfowl consume lead shot.[203] Because of their different feeding habits and habitats, waterfowl species vary widely in their consumption of lead pellets. As seen in Figure 4, bay diving ducks such as canvasback, lesser scaup, redhead, and ring-necked duck suffered from the highest rate of shot ingestion (12-14 percent) from 1938 to 1953; ducks such as the mallard, black duck, and pintail ingested lead shot at an intermediate rate (7-9 percent); and waterfowl including the green-winged teal, shoveler, wood duck, gadwall, blue-winged teal, and wigeon had the lowest rates (1-3 percent).

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[198] Bellrose, F.C. 1959. "Lead Poisoning As A Mortality Factor in Waterfowl Populations." *Illinois Natural History Survey Bulletin* 27(3):235-288.

[199] Sanderson, Glen C. and Frank C. Bellrose. 1986. A Review of the Problem of Lead Poisoning in Waterfowl. *Illinois Natural History Survey*, Champaign, Illinois. Special Publication 4. 34pp. Jamestown ND: Northern Prairie Wildlife Research Center Home Page. Available at: http://www.npwrc.usgs.gov/resource/othrdata/pbpoison/pbpoison.htm.

[200] Bellrose, F.C. 1951. "Effects of ingested lead shot upon waterfowl populations." *North American Wildlife Conference Transactions* 16:125-133.

[201] Bellrose, F.C. 1959. "Lead Poisoning As A Mortality Factor in Waterfowl Populations." *Illinois Natural History Survey Bulletin* 27(3):235-288.

[202] Sanderson, Glen C. and Frank C. Bellrose. 1986. A Review of the Problem of Lead Poisoning in Waterfowl. *Illinois Natural History Survey*, Champaign, Illinois. Special Publication 4. 34pp. Jamestown ND: Northern Prairie Wildlife Research Center Home Page. Available at: http://www.npwrc.usgs.gov/resource/othrdata/pbpoison/pbpoison.htm.

[203] Bellrose, F.C. 1959. "Lead Poisoning As A Mortality Factor in Waterfowl Populations." *Illinois Natural History Survey Bulletin* 27(3):235-288.

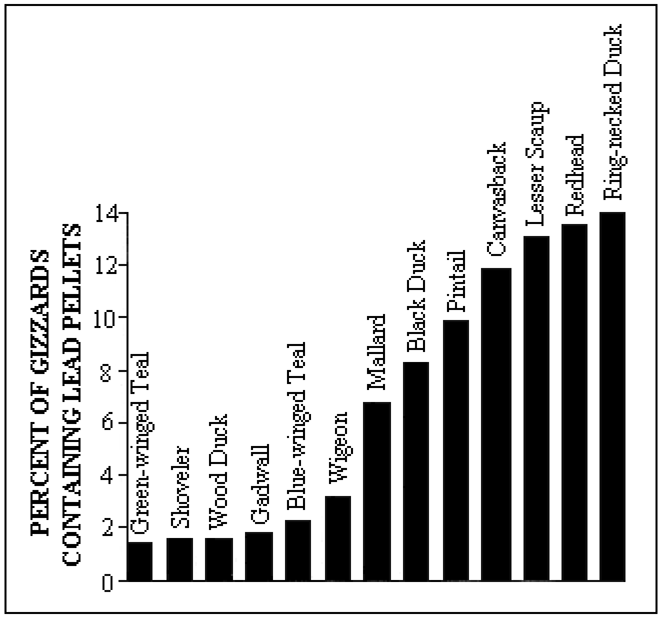


**Figure 4: Percentage of gizzards from various duck species containing ingested lead shot. 35,220 gizzards were sampled at several North American locations from 1938-1953.**
Source: Bellrose, F.C. 1959. "Lead Poisoning As A Mortality Factor in Waterfowl Populations." *Illinois Natural History Survey Bulletin* 27(3):235-288.

More than 300,000 ducks and geese suffer from lead poisoning each year due to their ingestion of lead shot and bullets.[204] As many as 1.5 to 2.5 million waterfowl died each year from lead poisoning until 1991, when the U.S. Fish & Wildlife Service banned use of lead shot for hunting them.[205] Finland and the Netherlands have also banned lead shot for waterfowl hunting, and the United Kingdom has a voluntary ban in place on the use of lead shot in wetland areas.[206]

Waterfowl can and do ingest lead from sources, but the U.S. Fish and Wildlife Service has stated that spent lead pellets are the primary source of lead exposure for wild waterfowl.[207] Other lead sources such as mine wastes,[208] lead fishing sinkers,[209] and

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[204] Kurt Kleiner, "Good news for ducks," *New Scientist*, August 30, 1997, p. 11.
[205] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.
[206] http://www.tintechnology.com/materials/detail/materials_projects_/Tin%20Shot.htm
[207] U.S. Fish and Wildlife Service 1976. "Final Environmental Statement: proposed use of steel shot for hunting waterfowl in the United States." U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C. 276 p.
[208] Niethammer, K.R. , R.D. Atkinson , T.S. Baskett, and F.B. Samson 1985. "Metals in riparian wildlife of the lead mining district of southeastern Missouri." Archives of Environmental Contamination and Toxicology 14:213-223.
[209] Gelston, W.L., and J. Stuht. 1975. "Successful treatment of a mute swan for lead poisoning." Jack-Pine Warbler 53(4):156-158.

atmospheric lead[210] have all been found to impact bird species, but this impact is minimal. Sources other than bullets and shot have only rarely been observed to cause lead poisoning or death.[211]

## Outdoor Lead Contamination

Lead contamination is a common problem at outdoor firing ranges. Leaded rounds typically fragment and corrode after hitting their targets. The debris that results then mixes with the soil, spreading lead and other heavy metal contamination.[212] One trap-shooting range in Naperville, Illinois, created over 230 tons of lead pollution near a high school over its 50 years of use.[213] After neighbors became concerned about possible lead contamination in wells and groundwater supplies, a court ruled (*Stone v. Naperville Park District, 1999*[214]) that firing at the range could not continue until a National Pollutant Discharge Elimination System (NPDES) permit was obtained. The range elected to discontinue shooting instead.

The Lordship Gun Club of Stratford, Connecticut, was also forced to close after the Second Circuit Court of Appeals ruled (*Connecticut Coastal Fishermen's Association v. Remington Arms Co., Inc*., *1993*) that the range was subject to Resource Conservation and Recovery Act (RCRA).[215] The Court wrote that, "After nearly 70 years of use, close to 2,400 tons of lead shot (5 million pounds) and 11 million pounds of clay target fragments were deposited on land around the club and in the adjacent waters of Long Island Sound."[216] These waters included two wildlife refuges. A study conducted in 1987 reported that 15 of 28 black ducks captured in the area suffered from acute lead poisoning, moist likely due to the Lordship trap and skeet range.[217]

According to the National Shooting Sports Foundation, several other ranges have been also been charged under the Clean Water Act and RCRA, but these ranges have either gone out of business, settled out of court, changed their shooting direction, or switched to

[210] Ohi, G., H. Seki, K. Akiyama, and H. Yagyu. 1974. "The pigeon, a sensor of lead pollution." *Bulletin of Environmental Contamination and Toxicology* 12(1):92-98.
[211] Sanderson, Glen C. and Frank C. Bellrose. 1986. A Review of the Problem of Lead Poisoning in Waterfowl. *Illinois Natural History Survey*, Champaign, Illinois. Special Publication 4. 34pp. Jamestown ND: Northern Prairie Wildlife Research Center Home Page. Available at: http://www.npwrc.usgs.gov/resource/othrdata/pbpoison/pbpoison.htm.
[212] Mitch Bryman, "Army Seeks Environmental Benefits from 'Unleaded' Bullets," 1997. Available at: http://aec.army.mil/usaec/publicaffairs/update/spr97/bullets.htm
[213] Linda Young, "Park Shooting Range Reopens After State Conducts Lead Tests," *Chicago Tribune*, 17 June 1997, p. 3.
[214] 38 F. Supp2d 651, 1999 U.S. Dist. LEXIS 1828 (NDIL 1999).
[215] See, "Lessons from Lordship," North American Hunting Club, *National Shooting Range Symposium: Proceedings* (1993), p. 73-79.
[216] *Conn. Coastal Fishermen's Assoc. v. Remington Arms Co., Inc.* 989 F.2d 1305, 1308 (2d Cir. 1993).
[217] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.

non-toxic shot.[218] To date, no outdoor firing range has obtained an NPDES permit, although by law every range is obligated to obtain one.[219]

U.S. military ranges have also suffered from the ill effects of led. By August of 1999, heavy lead contamination had forced the U.S. military to close more than 700 of its firing ranges.[220] The expense of cleaning up these ranges is unknown, but lead removal costs have been known to reach $300 to $500 per cubic yard of soil. Lead removal from just one Navy range cost $2.5 million, plus an additional $100,000 a year for environmental monitoring. High levels of lead have also forced the suspension of operations at more than 800 National Guard indoor firing ranges. Upgrades in the ventilation systems at these ranges will cost each range an estimated $150,000, or $122 million in total.[221]

Firing range cleanups can easily cost hundreds of thousands, if not millions, of dollars. The city of Port Salerno, Florida, was forced to pay $400,000 to clean up an abandoned range formerly used by the sheriff's office, after tests revealed high levels of lead contamination.[222] Port Richey, Florida, paid $50,000 to clean up children's play area that had unknowingly been built on the city's former firing range.[223] And New York City reportedly paid $25 million to remediate a police shooting range in the Bronx.[224]

City firing ranges aren't the only ranges that require expensive cleanups. Owners of a firing range in Wisconsin paid the U.S. government $1,000,000 in cleanup costs after 200 geese died of lead poisoning at the site. The cleanup of the former trap and skeet shooting range reportedly cost the government in excess of $1.75 million.[225] Federal taxpayers also footed the bill for the $200,000 Superfund cleanup cost of a former skeet shooting range in Delaware, nicknamed the "Harbeson Dead Swan Site." The nickname derives from the 41 dead black-billed tundra swans killed by lead poisoning at the site, reportedly one of

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[218] *Environmental Aspects of Construction and Management of Outdoor Shooting Ranges* (Newtown, CT: NSSF, 1997), p. I-9, 10.

[219] U.S. Environmental Protection Agency memorandum from Charles Sutfin, Director, Water Permits Division, to Jo Lynn Traub, Director, Water Management Division, "Proposed NPDES Permit for a Trap Shooting Facility," dated November 30, 1999.

[220] "Army Shoots for Safe Environment With Tungsten Bullets," *American Metal Market*, August 26, 1999, p. 4.

[221] Mitch Bryman, "Army Seeks Environmental Benefits from 'Unleaded' Bullets," 1997. Available at: http://aec.army.mil/usaec/publicaffairs/update/spr97/bullets.htm

[222] Edward Filo, "Range Cleanup at Final Phase," *The Stuart News/Port St. Lucie News* (Stuart, FL), 20 July 1999.

[223] Beth Glenn, "Kids' Play Area Causes Problem for Port Richey," *St. Petersburg Times*, 20 July 1998, p. 1.

[224] Violence Policy Center and Environmental Working Group, *Poisonous Pastime: The Health Risks of Shooting Ranges and Lead to Children, Families, and the Environment.* May, 2001.

[225] Gretchen Schuldt, "Firms Reach Cleanup Deal for ex-Playboy Club Site," *Milwaukee Journal Sentinel*, 2 October 1998, p. 2.

the highest ever kills of tundra swans.[226] More than $250,000 in taxpayer funding was required to pay for the cleanup of another private skeet-shooting range, located in the Prime Hook National Wildlife Refuge in Delaware.[227] The total number of firing ranges that will require eventual cleanup is unknown, but one Canadian remediation company estimated that 28,000 such sites may exist in the United States alone.[228]

## Impact on Human Health

Although the use of lead shot outdoors is considerably less dangerous to human health, some studies have indicated that lead poisoning may still occur. A 1989 study found that a class of police cadets in Richmond, Virginia had tripled their blood lead levels by the end of a five-day training class at an outdoor range. Another study found that a group of seven Los Angeles Police Department shooting instructors had all attained elevated blood lead levels from working at an uncovered outdoor shooting range.[229]

## Conclusion

The use of lead shot is dangerous to the environment, hazardous to human health, and expensive to clean up. Lead shot used outside of firing ranges is for all practical purposes irretrievable, and poses a potent threat to migrant birds and waterfowl. Lead shot fired at a firing range is likely to contribute either to hazardous indoor lead contamination or expensive outdoor lead contamination. In holistic terms, it makes little sense to continue the use of lead in bullets and shot, so long as practical alternatives exist.

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[226] Carl Weiser, "EPA Gets Lead Out On Dead Swan Site," *Gannett News Service*, 3 May 1999.
[227] "Officials: Skeet Range Polluted Wildlife Refuge," *Associated Press State & Local Wire*, 13 January 2000.
[228] "Soil cleanup firm starts first U.S. project," *Eco-Log Week* 23, no. 15 (1995).
[229] Sgt. W.R. Papple, Canadian Police Research Center "Toxic Free Ammunition - Ballistic Evaluation" TM-14-94 May, 1994. Available at: http://www.cprc.org/tm/1994/tm-14-94.pdf

# Section Seven

## Alternatives to Lead Use in Ammunition

Currently several alternatives exist to the use of lead in shot and bullets. Bismuth, copper, steel, tin, and tungsten ammunition is commercially available; of these, bismuth, steel, and tungsten have each passed rigorous toxicology tests and are approved by the United States Fish and Wildlife Service for the hunting of waterfowl.[230] Although these alternatives range widely in cost, availability, and ballistic performance, none them are as toxic as lead, or pose as great a threat to human health or the environment.

## Bismuth

Bismuth is a favored alternative to lead because bismuth bullets have similar penetration, striking energy and pattern characteristics to lead shot. Like lead, bismuth shots are effective at long range, and bullets made of bismuth do not ricochet off of hard surfaces. Bismuth bullets come in all gauges and shot sizes, and can be used in older or newer weapons without risk of harm. Bismuth is the only non-toxic shot currently available in .410, 28, and 16 gauge sizes.[231] However bismuth shot is expensive, due to its relative scarcity as a raw material. Bismuth shells can cost $2.00 each, or roughly eight to twelve times the going rate for lead bullets.[232]


Bismuth has been approved by the United States Fish and Wildlife Service as a non-toxic shot suitable for hunting waterfowl.[233] Birds and wildlife can eat bismuth pellets without risk of injury and humans can safely eat animals killed with bismuth rounds because metallic bismuth is not taken up by the digestive system.[234] However new research suggests that bismuth can be absorbed in potentially toxic amounts by waterfowl and other animals that are wounded by bismuth shot. A study conducted in 2000 by researchers in Australia and Denmark tested whether or not bismuth imbedded into the flesh of mice would be absorbed, and in what quantities. They found that after a matter of weeks bismuth had spread throughout their bodies, invading the kidneys, liver, spleen, lungs, spinal cord and brain tissue.[235]

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[230] US Environmental Protection Agency website, accessed January 17, 2003. See http://www.epa.gov/fedrgstr/EPA-IMPACT/2000/September/Day-06/i22721.htm
[231] See http://www.bismuth-notox.com/
[232] Best Management Practices for Lead at Outdoor Shooting Ranges, Appendix B. USEPA Region 2, December, 2000.
[233] U.S. Fish and Wildlife Service, 1997, "Approval of bismuth-tin shot as non-toxic for waterfowl and coots hunting," *Federal Register*, v. 62, no. 12, January 31, p. 4873-4876.
[234] David Adam, "Toxic Shot Syndrome," April 12, 2000. Available at: www.nature.com/nsu/000413/000413-7.html
[235] Pamphlett, R., Danscher G., Rungby, J., Stoltenberg, M. "Tissue Uptake of Bismuth from Shotgun Pellets" *Environmental Research* 82, 258 - 262 (2000).

This means that the use of bismuth could pose a threat to wounded wildlife. The number of waterfowl shot every year with bismuth shells is unclear, but those shot with bismuth are more likely to survive than those shot with lead, as bismuth is less dense and therefore less able to inflict damage. Toxicity to bismuth varies from one individual to the next, and is not directly related to the dose or duration of exposure. However exposure to bismuth has been associated with nervous system disorders, and research has concluded that there is “compelling evidence to suggest that exposure to bismuth should be kept to a minimum.”

To date, bismuth bullets are still considered non-toxic, and are fully supported by the U.S. Fish and Wildlife Service. Undoubtedly, bismuth shot, whatever its risk, poses a lesser threat to wildlife than the use of lead. However bismuth’s expense and its environmental risk make it the least attractive of all the non-toxic alternatives.

## Copper

Copper rounds are available for indoor and outdoor use in both hunting and target shooting. Copper bullets are considered non-toxic, work well in older and newer guns, and are equivalent to lead in terms of accuracy and functioning. The bullets are available at a weight equivalent to that of lead, improving performance, while the malleability of copper means that the risk of ricochet is reduced.[236] However only a few forms of copper ammunition are available, and these cost significantly more than standard lead rounds. Taurus copper rounds are available at $19.95 for a 20-round box.[237]



## Steel

Steel shot is an attractive alternative to lead because it is both widely available and only slightly more expensive than conventional leaded shot. Steel is also environmentally benign, and has been granted the approval of the U.S. Fish and Wildlife Service for waterfowl hunting.[238] Performance testing conducted by the Cooperative North American Shotgun Education Program (CONSEP) indicates that steel shot performs similarly to lead at short and medium ranges. However at longer ranges, steel is less effective because it is only two-thirds as dense as lead. The initial velocity of steel shot must be increased

236 http://www.dfafrangible.com/product.html
237 http://www.taurususa.com/products/products-ammo-45.cfm
238 The Michigan Department of Environmental Quality. http://www.michigan.gov/deq/0,1607,7-135-3585_4127_13090-25479--,00.html

in order to compensate for its lesser density and preserve downrange energy. Larger and heavier shot is therefore often used in hunting situations.[239]

Another concern with steel is its malleability. Steel is much harder than lead, and can cause the problem known as 'ring bulge' in older guns, particularly if a tight choke is used. Steel's hardness is also a safety concern, because it makes steel shot far more likely to ricochet when it comes into contact with hard surfaces. Many target shooters are also concerned that the use of steel shot will harm their scoring performance.[240] This has meant that steel shot is often used only grudgingly, if at all, by many hunters and shooters.

## Tin

Bullets made of tin are now commercially available and perform similarly to lead in terms of accuracy and functioning. Tin bullets have an advantage over other lead-free rounds in that they are softer, making them less likely to ricochet and pose a hazard. However tin bullets are also less dense, and therefore exhibit reduced performance at long ranges. As in the case of steel, larger shot sizes are required to compensate for reduced energies downrange.

Tin is non-toxic, although it has yet to be certified as such by the US Fish and Wildlife service for use in waterfowl hunting.[241] Tin-plated food cans have been used for over a hundred years, and have never demonstrated any health effects. Food from over 300 million tin cans is consumed on a daily basis.[242] Research has also indicated that tin shot is safe for waterfowl, and produces no ill effects in wildlife populations.[243]


Tin rounds first became available in 1998, when Winchester unveiled its 'Super Clean NT' round for both indoor and outdoor use. A second, higher-density generation is now in development which promises to perform better at greater distances. The US military is researching the use of tin for its "Green Bullets" program, and preliminary testing through the Armament and Munitions Research and Development Capability (ARDEC) has been promising.[244] However tin rounds are currently only available for six kinds of weapons: the 9 mm Luger, .357 Magnum, .357 Sig, .38 Special, .40 Smith &

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[239] Best Management Practices for Lead at Outdoor Shooting Ranges, Appendix B. USEPA Region 2, December, 2000.
[240] Ibid.
[241] http://sites.state.pa.us/PA_Exec/PGC/newsroom/2001news/nr63-01.htm
[242] International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Tin%20Shot.htm
[243] Grandy J. et al, "Relative Toxicity of Lead and Five Proposed Substitute Shot Types to Pen-reared Mallards," *J.Wild. Man.*, 1968, 32, p.483.

Wesson, and the .45 automatic. These rounds are also three times more expensive than standard lead shot, costing up to $32.65 for a 50-round box.[245]

## Tungsten

Tungsten—a metal typically used in light bulbs and cutting tools—is replacing lead shot in a variety of combinations. Tungsten/iron and tungsten/polymer shot is currently available, and the US military is in the process of replacing all of its 5.56 mm, 7.62 mm, 9 mm and .50-caliber lead ammunition with tungsten composite ammunition.[246] Tungsten bullets are suitable for combat and approved by the United States Fish and Wildlife Service (USFWS) for the hunting of waterfowl.[247] Testing conducted by the US military indicates that tungsten composite bullets meet or exceed function, accuracy, lethality and penetration performance requirements.[248]

**Figure 5: The tungsten-core 5.56 mm round on the left performs the same as the lead-core round on the right.**

Tungsten/iron shot is composed of 40% tungsten and 60% iron and has a density 94% that of lead. Tungsten/polymer shot is 95.9% tungsten and only 4.1% polymer, and has a density comparable to that of lead. Tungsten is easier to recycle than lead, and unlike leaded shot, tungsten rounds do not break up on impact, making recovery easier.[249] The elemental tungsten used in shot is insoluble and stable with acids. Tungsten does not easily form compounds with other substances and does not weather or degrade in the ambient environment.[250]

The USFWS has certified both forms of tungsten shot as nontoxic, and several studies have found that tungsten shot ingestion by fish or mammals is no basis for concern.[251] In one study, 20 8-week-old mallards were fed between 12-17 tungsten pellets and were

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[244] International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Tin%20Bullets.htm

[245] Winchester website, accessed February 19, 2003. See www.winchester.com

[246] Col. Stanley Lillie, Maj. Mark T. Corbett and Rick O'Donnell. "How Much Does a Bullet Cost?" *Army Magazine*, May, 2002. Available at: http://www.ausa.org/www/armymag.nsf/(all)/C29B7A7BA265E77385256B9E00717219?OpenDocument

[247] US Environmental Protection Agency website, accessed December 12, 2002. See http://www.epa.gov/fedrgstr/EPA-IMPACT/2000/September/Day-06/i22721.htm

[248] Col. Stanley Lillie, Maj. Mark T. Corbett and Rick O'Donnell. "How Much Does a Bullet Cost?" *Army Magazine*, May, 2002. Available at: http://www.ausa.org/www/armymag.nsf/(all)/C29B7A7BA265E77385256B9E00717219?OpenDocument

[249] 1st Lt. Brad Leighton, "Successful First Firing of Green Ammunition," March 26, 2002. Available at: http://aec.army.mil/usaec/publicaffairs/publicity02.html

[250] Kabata-Pendias, A. and H. Pendias. 1984. *Trace Elements in Soil and Plants*. CRC Press, Inc. Boca Raton, FL.

[251] Bursian, S.J., R.M. Mitchell, R.J. Tempelman, R.J. Aulerich, and S.D. Fitzgerald. 1999. "Chronic dosing study to assess the health and reproductive effects of tungsten-iron and tungsten-polymer shot on game-farm mallards." Report to Federal Cartridge Co. 115 pp.

monitored over the course of 32 days. No evidence of toxicity or tissue damage was found, leading the authors to conclude that the shot "presents virtually no potential for acute intoxication in mallards."[252] Another study found that tungsten shot was not toxic and had no systemic effects when embedded in the muscle tissue of mallards.[253] A third study fed tungsten to laying chickens in feed at a rate of 0.4 or 1.0 grams/kg to assess whether the metal had an impact on reproductive performance. The study found that

**Table 2: A Life-Cycle Comparison Between Tungsten and Leaded 5.56 mm Ammunition**

| Removal Method* | Cleanup Cost/Round | Total Cost/ Round (Lead) | Cleanup Cost (Lead)** | Total Cost (Lead)** | Cost of Leaded Bullets Over Tungsten*** |
|---|---|---|---|---|---|
| Wet Screen | 15 cents | 36 cents | $283,500 | $680,400 | $75,600 |
| Acid Wash | 65 cents | 86 cents | $1,228,500 | $1,625,400 | $1,020,600 |
| Dry Screen | 12 cents | 33 cents | $226,800 | $623,700 | $18,900 |
| Hazardous Waste Landfill | 77 cents | 98 cents | $1,455,300 | $1,852,200 | $1,247,400 |

**Based on the treatment of 3,636 tons of earth.*
*** Based on 1.89 million rounds*
****Based on an 11¢ premium per round.*

Source: Col. Stanley Lillie, Maj. Mark T. Corbett and Rick O'Donnell. "How Much Does a Bullet Cost?" *Army Magazine,* May, 2002.

weekly egg production was normal and that the eggs hatched at normal levels. When large doses of tungsten were injected directly into the chickens and concentrations reached 25 milligrams/gram in the liver, mortality resulted. However the study concluded that such high concentrations of tungsten were unlikely to occur in the environment, and would not occur because of the consumption of tungsten shot.[254] Subsequent short-[255] and long-term[256] toxicity studies have verified these results.

The US military is investing heavily in tungsten shot as part of its "Green Bullet" program, which aims to replace small-arms leaded shot with non-toxic alternatives by 2003.[257] The effort, spearheaded by the U.S. Army Armament Research, Development and Engineering Center (ARDEC), will eventually replace all of the 697 million leaded rounds that the military fires its 1,870 small arms training ranges in the United States.[258]

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[252] Ringelman, J.K., M.W. Miller, and W.F. Andelt. 1993. "Effects of ingested tungsten-bismuth-tin shot on captive mallards." *J. Wildl. Manage.* 57:725-732.
[253] Kraabel, F.W., M.W. Miller, D.M. Getzy, and J.K. Ringleman. 1996. "Effects of embedded tungsten-bismuth-tin shot and steel shot on mallards." *J. Wildl. Dis*. 38(1):1-8.
[254] Nell, J.A., E.F. Annison, and D. Balnave. 1981. "The influence of tungsten on the molybdenum status of poultry." *Br. Poult. Sci.* 21:193-202.
[255] Wildlife International, Ltd. 1998. "Tungsten-matrix shot: An oral toxicity study with the mallard." Project No. 475-101. 162 pp.
[256] Gallagher, S.P., J.B. Beavers, R. Van Hoven, M. Jaber. 2000. "Tungsten-matrix shot: A chronic exposure study with the mallard including reproductive parameters." Wildlife International, Ltd. Project No. 475-102. Easton, Maryland. 324 pp.
[257] 1st Lt. Brad Leighton, "Successful First Firing of Green Ammunition," March 26, 2002. Available at: http://aec.army.mil/usaec/publicaffairs/publicity02.html
[258] Mitch Bryman, "Army Seeks Environmental Benefits from 'Unleaded' Bullets," 1997. Available at: http://aec.army.mil/usaec/publicaffairs/update/spr97/bullets.htm

Copper-jacketed tungsten 5.56mm bullets are already being mass-produced at an average cost of two cents more per round. However the army expects that the price of tungsten bullets will decline to one to five cents less per round than leaded bullets once economies of scale set in. This will save the armed services between $3 million and $20 million per year in ammunition costs, and millions more in averted range cleanup costs.[259]

**Table 3: An Examination of Lead Shot Alternatives[a]**

| Shot Material | Cost per 25 Round Box[b] | Ballistic Performance | Availability | Comments |
|---|---|---|---|---|
| *Lead* | $5.00 per box<br>$3.00-$4.00 per box of reloaded shells | An accepted standard against which all other forms of ammunition are compared. | Widely available. | Lead is heavy, malleable, and poisonous. |
| *Bismuth*[c] (97% bismuth, 3% tin) | $37.50-$62.50 (bismuth shells are available in 10 round boxes at $15.00-$25.00 each)<br>$2.00 per shell | Similar to lead | There is only a limited world supply of bismuth. | The addition of tin to bismuth makes it more malleable and reduces fragility. Bismuth shot is safe to use in older firearms. |
| *Steel*[c] | $8.00-$12.95 per box<br>$6.00 per box of reloaded shells<br>$15.00 per box of copper-plated shells | Testing has concluded that in hunting situations, no appreciable differences exist between lead and steel shot at reasonable ranges. Lead is more effective at longer ranges. | Widely available from both domestic and imported sources. | Steel shot may cause 'ring bulge' in older guns if a tight choke is used.<br><br>Another concern with steel shot is its safety. As steel shot is much less malleable than lead, steel shot is much more likely to ricochet when it strikes hard surfaces. |
| *Tungsten/ Iron*[c] (40% tungsten, 60% iron) | $62.50 per box (tungsten/iron shots are packed in 10 round boxes at $25.00 each) | Preliminary reports indicate that tungsten/iron shot is just as effective as lead shot. However the amount of shot in each cartridge is significantly less than in typical lead cartridges or steel cartridges. | Widely available. | Tungsten/iron shot may cause damage to older guns similar to that of steel. |
| *Tungsten/ polymer*[c] | Data not available | Comparable to tungsten/iron | Recently made available | This shot may cause less damage to older guns, due to its increased malleability. |

[a] Information derived from Best Management Practices for Lead at Outdoor Shooting Ranges, Appendix B. USEPA Region 2, December, 2000.
[b] Costs are approximate, and will vary from store to store. Prices valid as of December, 2000.
[c] Has been approved by the United States Fish and Wildlife Service as a non-toxic material suitable for use in waterfowl hunting.

[259] 1st Lt. Brad Leighton, "Successful First Firing of Green Ammunition," March 26, 2002. Available at: http://aec.army.mil/usaec/publicaffairs/publicity02.html

# **Section Eight**

## Lead Use in Wheel Weights

Lead wheel weights are used worldwide to balance vehicle tires.[260] Automobile and light truck wheel weights vary in size and weight, ranging between 5-150 mm [0.2-6 in] in length and 7-113g [0.25-4oz] in weight.[261] Lead weights contain approximately 5% antimony (an alloy known as antimonious lead) to increase their hardness. The majority of wheel weights currently in use are clip-on types that are attached at the edge (horn) of a wheel's rim; however some new aluminum rims require adhesive weights due to their shape.

All vehicles require wheel weights to ensure tire balance and prevent vibration at high speeds.[262] An estimated 64 million kg/year [70,000 ton/year] of lead is used worldwide in the manufacture of wheel weights.[263] Approximately 40 million kilograms [88 million lb] of this lead may be rolling over U.S. highways each year, as the U.S. vehicle fleet comprises more than 200 million vehicles and each one contains between 200 and 250 grams of lead in wheel weights.[264] This amounts to 1.5-2% of an average vehicle's total lead use by weight (13 kg), or 10-12.5% of lead use, excluding the vehicle's lead-acid battery.[265]

**Figure 6: A selection of clip-on and adhesive wheel weights.**

An average vehicle contains ten wheel weights (two on each of the four wheels and two more on the spare).[266] Although many of these weights are collected during tire replacement and recycled, they can also end up in the environment or as contaminants in the metals recycling process. A disturbingly large number fall off onto the road during vehicle use. In October of 2001, Dr. Robert A. Root published a study documenting the rates at which these weights fall off their host vehicles and are gradually abraded into lead dust. His study was the first to examine this

[260] Personal interview with Jeff Gearhart, Auto Policy Director at the Ecology Center of Ann Arbor, January 13, 2003.
[261] Root, Robert A. *Lead Loading of Urban Streets by Motor Vehicle Wheel Weights. Environmental Health Perspectives*, Volume 108, Number 10. October 2000.
[262] Personal interview with Jeff Gearhart, Auto Policy Director at the Ecology Center of Ann Arbor, January 13, 2003.
[263] International Tin Research Institute website, accessed January 17, 2003. See http://www.itri.co.uk/wweights.htm
[264] Personal interview with Jeff Gearhart, Auto Policy Director at the Ecology Center of Ann Arbor, January 13, 2003.
[265] Ibid.
[266] Lohse, et al. *Heavy Metals in Vehicles II*. Report compiled for the Directorate General Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities. Hamburg, Germany. July, 2001.

phenomenon, and it established that lead wheel weights are, in his words, "a major source of lead exposure that heretofore has not been recognized."[267]

## The Root Study

Dr. Root conducted his survey by walking along several roads in Albuquerque, NM, visually surveying the sidewalk adjacent to the roads, and retrieving any lead found along the outer curb, in the street, or on the sidewalk. Surveys were conducted at midday to ensure that the lead pieces were not obscured by curb-side shadows. Eight six-lane divided street segments, totaling 19.2 km [12 mi], with an average weekday traffic volume of 45,000 vehicles/day were initially surveyed, establishing a steady state baseline of lead deposition. Collected lead ranged from 0.35 to 1.1 kg/km [1.2 to 3.9 kg/mi], while the geometric mean was 0.50 kg/km [1.75 lb/mi]. Individual lead pieces averaged 21g [0.75 oz] each; the smallest weighed approximately 3 g [0.1 oz]. Nearly all the lead that was collected in the survey was found in the 0.6-m-[2 ft-]wide curb area: only 1% of the lead was found elsewhere, in the street or the sidewalk.[268]

**Figure 7: Buckets of lead weights collected by an auto mechanic.**

Dr. Root also conducted a biweekly survey of a 2.4-km [1.5 mi] six-lane divided street segment, lasting 46 weeks. The segment, designated JTML, had an average daily traffic flow of 41,500 vehicles/day. Although JTML's steady state level was 1.09 kg/km [3.8 lb/mi], Dr. Root found an average accumulation of 0.35 kg/km [1.2 lb/mi] of lead biweekly, an annual accumulation equivalent to 9.1 kg/km [32 lb/mi].[269]

Finally, a degradation study was conducted, in which a total of 7.0 kg [15.4 lb] of wheel weights were spread over 14 days onto a heavily-trafficked street. On the 15th day, the entire area was searched and lead was retrieved from all areas of the street and sidewalk. Only 4.0 kg [8.8 lb] of the lead was found, or 57 percent of the lead originally deposited. This is

**Figure 8: An example of wheel weight abrasion. Notice the deformity when compared to the weights in Figure 6.**

[267] Root, Robert A. *Lead Loading of Urban Streets by Motor Vehicle Wheel Weights. Environmental Health Perspectives*, Volume 108, Number 10. October 2000.
[268] Ibid.
[269] Ibid.

unsurprising, as metallic lead is very soft and highly malleable. No adjustment was made for wheel weights potentially lost from motor vehicles because the biweekly survey indicated that this quantity would be small and it would, in any case, add to the lead collected and thus reduce the estimated lead lost due to abrasion. Most of the wheel weights found were abraded, some severely, and many of the weights had been broken into two or more pieces. Approximately half of the wheel weight lead deposited onto the street was not visible after eight days.[270]

These results indicate that when wheel weights fall off on busy streets and highways they are rapidly worn away, and that a significant fraction of the lead deposited would thus not be found in a roadside survey. Dr. Root calculated that 2.72% of the lead deposited in a given day will be worn away by the following day. This figure, together with the 5% antimony content found in wheel weights, was used to estimate an annual lead deposition rate for JTML. Dr. Root estimates that an average of 11.8 kg/km [40 lb/mi] of lead is deposited each year along the 2.4-km [1.5-mi] length of JTML. This estimate is considered conservative, as the highway median was not surveyed for lead deposition, and the retrieval rate in any visual survey is bound to be less than optimal. Many pieces of lead are the size, shape, and color of other roadside debris. On those occasions when Dr. Root immediately retraced the survey route, approximately 10% more lead was found.[271]

Wheel weight deposition occurred more frequently in places where vehicles rapidly change momentum, such as at intersections, near side streets, and in the vicinity of businesses. Dr. Root estimates that fully 24.5 kg/km [85 lb/mi] of lead is deposited annually along the southwestern 600-m [0.3-mi] quarter of JTML, which contains most of the segment's businesses and which precedes a stoplight. Lead deposition rates are estimated to be even higher for the 45 m [150 ft] immediately preceding the stoplight; between 50 and 70 kg/km [175 to 250 lb/mi] may be deposited there annually.[272]

Lead deposition at these levels can pose grave dangers, and it occurs in an area (the curb at a traffic light intersection) where pedestrians are most likely to step. Accumulated lead dust can easily find its way into homes on the soles of shoes and the paws of pets. According to the federal government, 800 mg/ft$^2$ of lead on an outdoor surface such as a sidewalk qualifies as a lead hazard. According to Dr. Root's estimates, the lead deposition rates at this traffic intersection would meet the lead hazard standard between 10,200□ and 13,400 times each year, more than once every hour.[273]

Adjusting for wear, highway medians, and antimony content, Dr. Root estimates that wheel weights fall off on major Albuquerque thoroughfares at a rate of 3,730 kg/year [8,200 lb/year]. The highest rate of lead deposition occurs in urban areas because 60% of vehicle-miles traveled are urban. Urban lead deposition, which he estimates at 1.5 million

270 Ibid.
271 Ibid.
272 Ibid.
273 Ibid.

kg/year [3.3 million lb/year], poses a significant lead poisoning threat to poor and minority populations that are already overexposed to lead burdens.[274]

## Ann Arbor Street Survey Results

In the fall of 2001, I conducted a visual survey of two Ann Arbor thoroughfares in the hopes of confirming and extending Dr. Root's results. The methodology for this survey can be found in the introduction, on page 4. The study area, a one-mile stretch of Division and Huron streets, was surveyed initially to clear away accumulated lead and establish a baseline for comparison. Twenty-seven wheel weights were collected, weighing a total of 19.52 ounces [1.22 lbs]. Many showed signs of serious abrasion. Their average weight, 20.5 g, roughly equates with the weights that Dr. Root retrieved (weighing 21 g on average).

A total of twenty wheel weights were recovered during the course of the weekly surveys, weighing a total of 14.5 ounces [.906 lbs.]. Many of these weights also showed signs of abrasion. Their average weight, 20.6 g, again equates with the average weight of those that Dr. Root retrieved.

In the study conducted by Dr. Root, 15.7% of the lead found in the initial steady state survey was retrieved each week by weight (3.8 lbs of lead was found per mile in the steady state survey vs. 1.2 lbs per mile in the biweekly survey). In my own study, 18.6% of the lead found in the steady state survey was retrieved on a weekly basis. This higher weekly retrieval rate can only be explained by the smaller sample and shorter length of my study (four weeks vs. the 46-week length of Dr. Root's study).

Forty-seven wheel weights were retrieved in all over the course of my survey; fully 96% of these were found within 2 feet of the curb. These results accord with those of Dr. Root; 99% of the wheel weights he found were retrieved within 2 feet of the curb.

Dr. Root's study revealed that wheel weights fall off much more frequently in locations where vehicles are slowing down and changing momentum. My own study verified these results. Nearly 98% of the wheel weights I retrieved were found within 25 feet of an intersection (only one was not). This is an extremely high proportion that can partially be explained by the streets themselves: both Division and Huron are intersected every block by other streets in the area I surveyed.

Based on my results, I was able to calculate an estimate for the number of wheel weights that are lost per vehicle-mile/year. The adjusted daily traffic count for Huron and Division, 15,199.6 vehicles, can be multiplied by 365 to yield an annual traffic count of 5,547,854. The average number of wheel weights collected per week, five, can similarly be multiplied by 52 to yield an annual wheel weight deposition rate of 260. Considering that we surveyed a stretch of road one mile in length, our study found that .000046865 wheel weights are lost per vehicle-mile/year.

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[274] Ibid.

Dr. Root's results were a virtual match in this regard. Dr. Root doesn't reveal in his report the total number of wheel weights that he collected, but this data can be derived from other information contained in his study. He reports that he collected an average of 8.05 kg of lead per kilometer over the course of his 46 week survey. As his survey route was 2.4 km in length, Dr. Root therefore collected a total of 19.32 kg of lead. The lead wheel weights that he found weighed an average of 21 g, yielding a total of 920 wheel weights collected over the 46-week time period. Over a 52-week period, Dr. Root would have therefore found 1040 wheel weights.

The survey route that Dr. Root examined supported a daily traffic burden of 41,500 vehicles/day. Multiplying this number by 365, we find that the annual traffic burden of his survey area is 15,147,500. Given that his survey area was a full 1.5 miles in length, we find that .0000457721 wheel weights were lost per vehicle-mile/year in Dr. Root's study area. Dr. Root therefore found 97.67% as many wheel weights as I did, adjusted for survey distance and traffic counts.

## Ann Arbor Street Survey Conclusions

This correlation is highly significant, and suggests that the number of wheel weights lost per vehicle-mile/year is consistent nationwide. Additional research will be necessary to determine if this is, in fact, the case, but given that contact with the curb or a change in momentum appears to make wheel weights fall off of their host vehicles, and that both conditions occur throughout the nation, it seems likely that a consistent nationwide figure can be determined. Both surveys of wheel weight deposition rates thus far have been conducted in urban areas (in Albuquerque and Ann Arbor) where curbs are present and where stop-and-go traffic is most frequent. It seems possible that wheel weights would fall off less frequently on interstates and freeways—where speeds are more consistent and curbs are lacking—but this has not been studied.

If the number of wheel weights lost per vehicle-mile/year is consistent, as suggested, it becomes possible to calculate the number of wheel weights lost annually in the United States, and the quantity of lead that is thus deposited upon roads and highways. The average number of wheel weights lost per vehicle-mile/year across both studies is 0.0000463186; given that there were 2.778 trillion vehicle-miles traveled in 2001,[275] it appears that 128,672,973 wheel weights may have been lost on American roads and highways in 2001. If these wheel weights weigh an average of 21 g, as both studies have suggested, 2,702,132 kg [5,957,082 lbs] of lead may have been deposited on the nation's highways in 2001.

These figures suggest a serious health threat, particularly in urban areas, where 60% of all vehicle-miles are traveled.[276] Testing of roadside soil has frequently revealed lead levels

[275] National Highway Traffic Safety Administration testimony before Congress, June 27, 2002. Available at http://www.nhtsa.dot.gov/nhtsa/announce/testimony/HWYSafetyUpdate.html
[276] U.S. DOT. Table 1-29. Roadway Vehicle-Miles Traveled (VMT) and VMT per Lane Mile by Functional Class. Available at http://www.bts.gov/ntda/nts/nts99/data/Chapter1/1-29

as high as 10,000 parts per million.[277] Although the EPA has attributed these lead levels to the prior use of leaded gasoline,[278] it seems likely, in light of this research, that lead wheel weight abrasion and the resultant lead dust contributes heavily to roadside lead contamination.

## Ann Arbor Parking Survey Results

I also conducted a survey of parked vehicles in the fall of 2001, in the hopes of expanding upon Dr. Root's original study. Several area parking garages were surveyed with the intention of determining how many had retained their quota of lead wheel weights. The complete methodology for this survey can be found on page five of the in the introduction.

A total of 926 wheel weights were found missing, as shown in Table 1. On average, one

*Table 4: Wheel Weights Lost*

| Company | Total Cars | Total Wheel Weights Lost | Weights Lost per Vehicle |
|---|---|---|---|
| Audi | 4 | 4 | 1 |
| DaimlerChrysler | 160 | 154 | 0.963 |
| Ford | 268 | 290 | 1.082 |
| GM | 219 | 250 | 1.142 |
| Saab | 9 | 8 | 0.889 |
| Honda | 92 | 78 | 0.848 |
| Nissan | 21 | 22 | 1.048 |
| Subaru | 23 | 22 | 0.957 |
| Toyota | 61 | 70 | 1.148 |
| Volkswagen | 20 | 28 | 1.4 |
| **Total** | 877 | 926 | 1.056 |

wheel weight was found missing per vehicle. Assuming that missing wheel weights are replaced on an annual basis,[279] it becomes possible to compare the results of this survey to the street survey results obtained in Ann Arbor and Albuquerque. As there are 200 million vehicles in use in the United States today,[280] and as these vehicles traveled a total of 2.778 trillion miles in 2001,[281] the average vehicle travels 13,890 miles per year. If each vehicle travels 13,890 miles per year, than the surveyed vehicles travel a total of

[277] ATSDR. The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress. Atlanta, GA: Agency for Toxic Substances and Disease Registry, 1988.
[278] U.S. EPA. "Soil Near Street." Available at http://www.epa.gov/grtlakes/seahome/leadenv/src/soilnr.htm
[279] Rebalancing is recommended every other time the tires are rotated; rotations are recommended every 6,000 miles. As the average vehicle travels some 14,000 miles per year, it should have its tires rebalanced once per year. See http://www.goodyeartires.com/faqs/Balancing.html and http://www.renosbrake.com/services/.
[280] Personal interview with Jeff Gearhart, Auto Policy Director at the Ecology Center of Ann Arbor, January 13, 2003.
[281] National Highway Traffic Safety Administration testimony before Congress, June 27, 2002. Available at http://www.nhtsa.dot.gov/nhtsa/announce/testimony/HWYSafetyUpdate.html

12,181,530 miles each year. Given the total number of wheel weights lost, 926, it appears that 0.0000760167 wheel weights are lost per vehicle-mile/year.

## Ann Arbor Parking Survey Conclusions

This number is significantly different from that obtained by the Albuquerque and Ann Arbor surveys. The two street surveys combined recovered only 61% of the wheel weights that the parking structure survey indicated should be there. This lower recovery figure can be explained, at least in part, by the imperfect retrieval rate of street surveys: Dr. Root reported that when he immediately retraced his survey route, approximately 10% more lead was found.[282] The rest of the lead, it seems likely, cannot be found because it has already been abraded into fine lead dust. In his study, Dr. Root reported that wheel weights suffer from an impressive degradation rate of fully 2.72% per day. This rapid disintegration could easily account for the difference between the parking structure survey and the street surveys. The parking structure survey supports Dr. Root's degradation findings, and suggests that far more lead may be deposited each year on our nation's highways than his street survey indicated. If wheel weights are actually lost at a rate of 0.0000760167 per vehicle-mile/year, than as many as 211,174,458 weights may be lost each year, weighing in excess of 4,434,665 kg [9,776,595 lbs].

## Effects of Wheel Weight Deposition

Wheel weight lead deposition is "continuous, significant, and widespread, and is potentially a major source of human lead exposure," according to Dr. Root. My own research closely coincides with Dr. Root's findings, and suggests that between 6 million and 10 million pounds of lead may be deposited on our country's roads and highways each year. Dr. Root's findings indicate that this lead is rapidly abraded into fine dust particles, which are susceptible to atmospheric corrosion, and are expected to turn into lead oxides, hydroxides, and bicarbonates under ambient environmental conditions. These conversions make lead more soluble, and increase the risk that lead will contaminate surface, groundwater, and drinking water supplies. Soluble lead is also more easily absorbed by the human body, whether by ingestion or inhalation.

Lead dust created by wheel weight abrasion may contribute to the airborne lead concentrations of urban areas, as the turbulence that vehicles create sweeps street dust into the atmosphere. Lead dust may also adhere to the shoes of pedestrians or the feet of pets, from whence it would be tracked into and deposited in homes and workplaces. As

[282] Root, Robert A. *Lead Loading of Urban Streets by Motor Vehicle Wheel Weights. Environmental Health Perspectives*, Volume 108, Number 10. October 2000.

this lead has been abraded into small particles, it poses a significant risk of exposure via inhalation, in addition that of ingestion.

The lead dust created by the abrasion of fallen wheel weights is also likely contribute to the lead found in urban runoff. Rainwater can sweep accumulated lead dust into culverts, drains, and ultimately waterways, where it can adversely affect water quality, wildlife, and aquatic ecosystems. One study of urban runoff in Washington, D.C. estimated that over a 10-month period, fully 22,000 pounds of lead had been carried into area rivers and streams by runoff from impervious areas.[283] Studies conducted in Madison, Wisconsin, have shown that approximately 40% of the runoff from residential areas and 70% of the runoff from commercial areas had lead levels “high enough to kill aquatic life.” Concentrations of lead in Madison’s runoff ranged from 3-160 µg/L.[284] “The primary source of many metals in urban runoff is vehicle traffic,” the authors write. “Concentrations of zinc, cadmium, chromium and lead appear to be directly correlated with the volume of traffic on streets that drain into a storm sewer system. Streets and parking lots are the primary sources of lead in urban [runoff].”[285]

In the absence of leaded gasoline, lead wheel weight deposition and degradation may be one of the primary sources of urban lead contamination and exposure. The lead dust created by wheel weight abrasion is difficult to retrieve, and seems likely to contribute to the permanent lead burdens of urban areas. This contamination will continue to impact human and environmental health until lead wheel weights are exchanged for a safer alternative.

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[283] http://eces.org/articles/static/97080840044714.shtml

[284] University of Wisconsin-Extension, Wisconsin Department of Natural Resources *Urban Runoff: How Polluted Is It?* 1995. Available at: www.env21.com/DocShareLight/Upload/ Project12/URBAN%20RUNOFF(1).doc

[285] Carolyn D. Johnson and Dotty Juengst, University of Wisconsin-Extension, Wisconsin Department of Natural Resources *Polluted Urban Runoff : A Source of Concern* I-02-97-5M-20-S DNR: WT-483-97 Available at clean-water.uwex.edu/pubs/sheets/hiurban.pdf

# Section Nine
## Alternatives to Lead Use in Wheel Weights

A number of governments have already begun to recognize the threat that lead pollution from wheel weight degradation poses to human health and the environment. Japan has called for a drastic voluntary reduction in the use of lead in vehicles, and Nissan and Toyota have both responded. Nissan has stated that it will reduce most uses of lead in vehicles by fully two-thirds by 2005, and Toyota has called the reduction of lead use in its vehicles an "urgent objective."[286] The Japan Automobile Manufacturers Association (JAMA) aims to cut all uses of lead, excepting batteries, to one-third of 1996 levels by 2005. Perhaps most significantly, the European Union has amended its directive on end-of-life vehicles to ban the use of leaded wheel weights by 2005. This ban applies to all vehicles type-approved before July 1st, 2003, and the wheel weights intended for servicing those vehicles.[287] The ban will be reviewed for its impact on road safety prior to taking hold, but promises to eliminate the threat that leaded wheel weights pose and replace them with more responsible alternatives.

A variety of alternatives have been considered, including the use of tin, steel, tungsten, plastic (thermoplastic polypropylene), and ZAMA (an alloy of zinc, aluminum, and copper).[288] Plastic beads are in use today, although primarily in American trucks and commercial vehicles. The beads are injected into the tire and allowed to roll around inside it, balancing the vehicle while driving. However the beads are primarily effective only in larger vehicles, and their disadvantages have prevented wider use.[289]

Steel wheel weights have been in production since June of 1998, when Azuma, a Japanese company, began manufacturing adhesive steel weights. Clip-on steel weights have been available since April of 2001, but a number of disadvantages have prevented their wide acceptance. Firstly, steel clip-on weights, unlike lead or tin, cannot be manufactured with an integral clip, as the clip would melt in typical molding injection processes. A separate clip must be attached to the weight,

**Figure 9: A selection of the steel clip-on weights produced by the Japanese company Azuma.**

[286] International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Wheel%20Weights.htm
[287] 2002/525/EC, Commission Decision of 27 June 2002 Amending Annex II of Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles. *Official Journal of the European Communities* June 29, 2002 L170/81.
[288] Personal interview with Jeff Gearhart, Auto Policy Director at the Ecology Center of Ann Arbor, January 13, 2003.
[289] International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Wheel%20Weights.htm

increasing the cost and time of manufacture. Additional corrosion-resistant coatings are also necessary for steel weights to prevent rusting and disintegration. Although steel is cheap and plentiful, the production of steel weights is a relatively high-cost process, one that involves expensive capital equipment, increased die wear, and a significant departure from existing production processes. Finally, steel's hardness is a drawback, as the installation of these weights is likely to cause damage to alloy wheel coatings, thereby marring the wheel's appearance and corrosion resistance. The use of non-malleable weights causes particularly severe problems in the aftermarket, as tires are rebalanced. Rebalancing weights account for fully two-thirds of all wheel weight sales; although lead and tin weights can be spot-adjusted to fit almost any type of rim, precise designs are required for non-malleable weights to fit a rim without causing undue damage. Fortunately, these problems are not as severe for adhesive steel weights, which are uniform in appearance and can fit any type of rim with the proper adhesive. The production costs of adhesive steel weights still exceed those for lead, but the cheap value of raw steel makes it an attractive and inexpensive alternative to adhesive lead weights.


**Figure 10: A selection of the steel adhesive weights produced by Azuma.**

ZAMA weights have many of the same drawbacks as steel weights. They require the same corrosion-resistant coatings and clip-fixture processes that increase the costs of steel weights. Zinc, like steel, is a hard metal, and is likely to harm alloy wheel coatings during installation. Unlike steel, zinc has been rejected by the US Fish and Wildlife Service for use in non-toxic ammunition and shot; zinc is an eco-toxin itself, and while it might present a lesser threat than lead, the threat is not insignificant. All of these factors have made ZAMA weights an unattractive alternative to lead weights.

Polypropylene weights are also an unattractive alternative. Although made of plastic, polypropylene weights are non-malleable, presenting similar difficulties to those of steel and zinc in application. As a thermoplastic, polypropylene weights will deform under heating, and polypropylene is subject to degradation through the exposure to UV light. Finally, the raw material cost of polypropylene is roughly twice that of lead, explaining the reluctance of most weight manufacturers to launch a polypropylene line.

Today, tin appears to be the obvious alternative to lead use in wheel weights. Tin weights can be formed and cut in the same way as lead weights, using existing production processes without substantial modification. Although some changes are required to the equipment set-up and control mechanisms, these can be achieved at relatively low cost. This makes tin a "drop-in" replacement for lead from a production standpoint. Quality tin weights can be produced within six months of a trial initiation.

Tin weights have a suitable malleability and adhesion to the clip, and are resistant to corrosion. Production and performance trials are now complete, and have shown that these weights enjoy the same performance as traditional lead wheel weights. Tin weights are also bright and attractive, an improvement upon lead wheel weights, which often had to be coated or plated to prevent lead's dull color from ruining the appearance of shiny alloy wheels.[290]

Tin is non-toxic, and is expected to be a safe and environmentally-friendly replacement for lead use in wheel weights. Research has indicated that tin exposure is benign in wildlife populations,[291] and exposure to tin is considered harmless to humans. Tin-plated food cans have been in use over a hundred years, and have never demonstrated any ill effects. The International Tin Research Institute estimates that food from over 300 million tin cans is eaten on a daily basis.[292] Tin's lack of human and environmental health impacts is in marked contrast to those of lead.

**Figure 11: Some of the tin clip-on weights produced by the British company TRAX.**

Tin's only drawback is its density. For the same cross-section, a tin weight will have to be about 50% longer than a comparable lead weight in order to achieve the same balancing effect.[293] However these larger tin wheel weights can be easily accommodated by the majority of the vehicle market.[294]

One of Europe's major wheel weight manufacturers, TRAX, is now producing wheel weights made entirely from tin. A wide range of tin wheel weights are now commercially available, and it is expected that these tin weights will become dominant in the European market over the next few years.[295] Although tin weights are more expensive than lead weights, due to the increased raw material cost—tin weights cost approximately 16 cents more than lead wheel weights, a cost increase of $1.60 per vehicle—this cost is negligible when compared to the ongoing environmental and health costs of continued lead use.

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290 Ibid.
291 Grandy J. et al, "Relative Toxicity of Lead and Five Proposed Substitute Shot Types to Pen-reared Mallards," *J.Wild. Man.*, 1968, 32, p.483.
292 International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Tin%20Shot.htm
293 TRAX website, accessed February 10, 2003. See http://www.traxadm.demon.co.uk/tin1.html
294 International Tin Research Institute website, accessed January 14, 2003. See http://www.tintechnology.com/materials/detail/materials_projects_/Wheel%20Weights.htm
295 Ibid.

# Section Ten
## Conclusions and Recommendations

In 1983, a report by Britain's Royal Commission on Environmental Pollution concluded that man had dispersed lead so widely in the twentieth century that "it is doubtful whether any part of the earth's surface or any form of life remains uncontaminated by anthropogenic lead."[296] This is a damning conclusion. Given lead's unquestioned toxicity, it's also a dangerous one. Public health organizations and agencies as diverse as the Centers for Disease Control, the American Academy of Pediatrics, the Environmental Protection Agency and the National Academy of Sciences have all agreed that lead poses a formidable threat to human health at levels as low as 10 µg/dl of human blood, "an unprecedented coherence of opinion in the field of neurotoxicology."[297] In 1994, several prominent lead research doctors declared that the case against lead is so conclusive that "if this massive database is not persuasive…then no other chemical can be considered to have been demonstrated to be toxic."[298]

In light of this extreme toxicity, it makes sense to limit all possible exposure routes to lead. Unfortunately, the federal government has often taken years, sometimes decades, to ban uses of lead that posed a severe environmental or health threat. This pattern seems likely to continue. Although a vast number of studies have linked the use of lead ammunition to lead poisoning and environmental contamination, the use has been allowed to continue, with the sole exception of waterfowl hunting. This is in marked contrast to Denmark, which banned all uses of lead ammunition in 1996.[299] Hunters there have switched to steel or bismuth shot, without noticeable difficulty. Given the recent development of tungsten ammunition, which is as effective as lead and available at nearly the same cost, there remains no justifiable reason to continue the use of leaded ammunition.

The use of lead wheel weights has not been studied as thoroughly as the use of lead ammunition, but there seems to be little doubt that wheel weight lead also poses a threat. Dr. Root's study concluded that as much as 3.3 million pounds of lead may be deposited each year on urban streets and freeways. My own research has indicated that between six and ten million pounds may be deposited each year throughout the United States. Given lead's propensity to abrade, particularly under the stress of heavy traffic, it seems likely that vast quantities of lead dust are being created. The environmental and health impacts of such a large lead burden can only be guessed at. The European Union is already moving to phase out lead wheel weights; a complete ban will be in place by 2005. Although there are numerous alternatives to lead, tin seems to be the most promising; tin

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[296] Jamie Lincoln Kitman, "The Secret History of Lead." *The Nation*, 20 March 2000. Available at: http://thenation.com/doc.mhtml?i=20000320&c=18&s=kitman.
[297] Ibid.
[298] Ibid.
[299] http://www.unep-wcmc.org/AEWA/eng/leadpage7.htm

wheel weights can be manufactured using existing production processes and at only slightly higher cost.

Despite the danger associated with lead use in ammunition and wheel weights and despite the alternatives that are commercially available, the United States government has given no indication that it is inclined to adopt the Danish or EU bans. This is not out of keeping with past history, but it should not dissuade corporations from taking proactive action. Indeed, the doctrine of Producer Responsibility dictates that proactive efforts to protect the environment and human health should be at the very heart of corporate behavior. In many instances, and often with great success, producer responsibility has been legislated and integrated into policies and regulations, but it need not be. The imperative to act in the public interest remains.

The producers of leaded ammunition and wheel weights should discontinue the use of lead and switch to safer and more responsible alternatives. So long as lead is used, poisoning and contamination will inevitably result. No compelling reason exists to continue the use of such a toxic substance; lacking one, common decency dictates that the use of lead be phased out, and alternative uses adopted.

# Appendix Alpha

## Selected Studies Documenting Lead Risks at Indoor Ranges


Philip J. Landrigan et al., "Chronic Lead Absorption: Result of Poor Ventilation in an Indoor Pistol Range," *Journal of the American Medical Association* 234, no. 4 (1975): 394;

Thomas L. Anania and Joseph A. Seta, *Lead Exposure and Design Considerations for Indoor Firing Ranges* (Washington, DC: National Institute for Occupational Safety and Health, 1975);

Karl E. Anderson et al., "Plumbism from Airborne Lead in a Firing Range," *The American Journal of Medicine* 63 (August 1977): 306;

A. Fischbein et al., "Exposure to Lead in Firing Ranges," *Journal of the American Medical Association* 241, no. 11 (1979): 1141;

S.A. Lee, "Reducing Airborne Lead Exposures in Indoor Firing Ranges," *FBI Law Enforcement Bulletin*, February 1986, p. 15;

Sarah E. Valway et al., "Lead Absorption in Indoor Firing Range Users," *American Journal of Public Health* 79 (August 1989): 1029;

T. Chau et al., "Chronic Lead Intoxication at an Indoor Firing Range in Taiwan," letter to the editor, *Clinical Toxicology* 33, no. 4 (1995): 371;

Burhan A. Abudhaise et al., "Lead Exposure in Indoor Firing Ranges: Environmental Impact and Health Risk to the Range Users," *International Journal of Occupational Medicine and Environmental Health* 9, no. 4 (1996): 323;

"Lead Health Hazard Evaluation: FBI Academy, Quantico, Virginia," HETA 91-0346-2572 (April 1996);

David C. Sylvain, "NIOSH Health Hazard Evaluation Report: Dartmouth Police Department," HETA 96-0107-2613 (December 1996).

# Appendix Beta

## Selected Studies of Lead Shot Ingestion Among Waterfowl

Ingestion rates of lead and steel shot pellets in selected species of game ducks as recorded in various states and flyways, 1973-84.[300]

| Flyway/State | Years | Investigator | Mallard | | Mottled/Black Duck | | Wood Duck | | Gadwall | | Wigeon | | Pintail | | Green-winged Teal | | Blue-winged Teal | | Shoveler | | Canvasback | | Redhead | | Ring-necked Duck | | Greater and Lesser Scaup | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No.[a] | %[b] | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No.[a] | %[b] | No. | % | No. | % | No. | % | No. | % | No. | % |
| **Atlantic** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Florida | 1973-78 | Baker & Thompson 1979 | 50 | 32.0 | 452[c] | 29.0 | - | - | 87 | 1.1 | 968 | 1.4 | 1,134 | 25.6 | 447 | 1.3 | 1,025 | 1.7 | 308 | 0.3 | 234 | 65.4 | 178 | 29.8 | 3,455 | 24.0 | 1,078 | 7.6 |
| Maine | 1976-80 | Longcore et al. 1982 | 164 | 3.0 | 506[d] | 6.9 | 9 | 0.0 | 2 | 0.0 | 9 | 0.0 | 42 | 2.4 | 397 | 0.3 | 111 | 1.8 | - | - | - | - | - | - | 5 | 20.0 | 1 | 0.0 |
| Maryland | | Scanlon et al. 1980 | 144 | 18.8 | 105 [d] | 21.9 | 14 | 0.0 | 17 | 0.0 | 16 | 0.0 | 10 | 10.0 | 17 | 0.0 | - | - | 4 | 2.5 | - | - | - | - | - | - | 9 | 0.0 |
| New York | 1977-82 | Moser 1983 | 8,154 | 12.1 | 3,450[d] | 8.7 | 1,204 | 1.6 | 295 | 1.0 | 581 | 1.0 | 224 | 6.7 | 803 | 1.2 | 343 | 0.3 | - | - | 209 | 6.2 | 199 | 6.0 | 107 | 7.5 | 592 | 7.9 |
| Florida | 1976-84 | Thul 1985 | 90 | 16.7 | 202[c] | 14.9 | 242 | 4.5 | 68 | 1.5 | 171 | 4.1 | 114 | 12.3 | 277 | 3.3 | 1,605 | 3.1 | 519 | 1.3 | 33 | 9.1 | 25 | 12.0 | 5,436 | 15.9 | 1,072 | 16.9 |
| **Subtotal & Mean** | | | **8,602** | **12.3** | **4,061** | **8.8** | **1,469** | **1.9** | **469** | **1.1** | **1,745** | **1.5** | **1,524** | **21.1** | **1,941** | **1.9** | **3,084** | **2.3** | **831** | **1.0** | **476** | **35.5** | **402** | **16.9** | **9,003** | **20.0** | **2,752** | **11.3** |
| **Mississippi** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arkansas | 1977-79 | Sullivan 1980 | 4,445 | 6.7 | 9[d] | 0.0 | 88 | 2.3 | 65 | 4.6 | 13 | 7.7 | 11 | 9.1 | 207[e] | 0.0 | - | - | 5 | 0.0 | 4 | 0.0 | 2 | 0.0 | 22 | 4.5 | 10 | 0.0 |
| Michigan | 1977-79 | Nelson & Johnson 1980 | 6,025 | 8.6 | 664[d] | 9.6 | 468 | 4.0 | 76 | 5.3 | 284 | 2.4 | 273 | 4.8 | 808 | 1.5 | 285 | 1.0 | 28 | 7.1 | 8 | 12.5 | 51 | 17.6 | 364 | 18.4 | 248 | 4.0 |
| Ohio | 1977-79 | Bednarik & Shieldcastle 1980 | 2,073 | 6.8 | 271[d] | 5.9 | 556 | 0.9 | 286 | 0.7 | 250 | 0.8 | 622 | 5.3 | 500 | 0.2 | 833 | 0.6 | 361 | 0.6 | - | - | 29 | 10.3 | 83 | 7.2 | 114 | 14.9 |
| Indiana | 1977-80 | Sporre & | 1,809 | 9.8 | 188[d] | 9.0 | - | - | - | - | - | - | 99 | 12.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

[300] Northern Prairie Wildlife Research Center website, http://www.npwrc.usgs.gov/resource/othrdata/pbpoison/ingested.htm. Accessed January 15, 2003.

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Blevins 1981 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Louisiana | 1974-81 | Smith 1981 | 6,834 | 15.2 | 611[c] | 26.4 | 378 | 2.6 | 422 | 1.4 | 182 | 2.2 | 3,956 | 16.6 | 555 | 1.8 | 2,251 | 6.4 | 155 | 1.3 | 13 | 7.7 | 14 | 28.6 | 205 | 14.1 | 523 | 26.8 |
| Missouri | 1978-81 | Humburg & Babcock 1982 | 14,638 | 6.0 | 2[d] | 0.0 | 32 | 0.0 | 100 | 2.0 | 141 | 0.7 | 472 | 5.7 | 262 | 0.0 | 59 | 0.0 | 67 | 3.0 | 8 | 12.5 | 34 | 0.0 | 438 | 13.0 | 92 | 4.3 |
| Illinois | 1979-82 | Anderson 1982 | 9,574 | 6.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 18 | 0.0 | 5 | 20.0 | 323 | 2.5 |
| **Subtotal & Mean** | | | **45,448** | **8.1** | **1,134** | **8.6** | **1,522** | **2.4** | **949** | **1.8** | **870** | **1.7** | **5,433** | **13.7** | **2,332** | **1.0** | **3,428** | **4.4** | **295** | **1.6** | **29** | **10.3** | **148** | **10.8** | **1,117** | **14.3** | **1,310** | **13.7** |
| **Central** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kansas | 1973-74 | Funk 1974 | 407 | 4.2 | - | - | - | - | - | - | - | - | 171 | 4.7 | - | - | - | - | - | - | - | - | - | - | - | - | 86 | 14.0 |
| N. Dakota | 1973,77,78 | Johnson 1985 | 746 | 0.8 | - | - | - | - | - | - | - | - | 57 | 1.8 | - | - | - | - | - | - | - | - | - | - | - | - | 27 | 0.0 |
| S. Dakota | 1973,83 | Funk 1974; Fowler & Simpson 1984 | 1,080 | 2.3 | - | - | - | - | - | - | - | - | 46 | 2.2 | - | - | - | - | - | - | - | - | - | - | - | - | 69 | 1.4 |
| Nebraska | 1973-83 | Funk 1974; Gabig 1984 | 4,643 | 1.1 | - | - | - | - | 181 | 0.0 | 216 | 0.0 | 258 | 0.8 | 197 | 0.5 | 193 | 0.5 | - | - | - | - | - | - | - | - | 78 | 1.3 |
| Oklahoma | 1979-84 | Due 1985 | 2,811 | 2.0 | - | - | 92 | 2.2 | 248 | 0.4 | 139 | 1.4 | 83 | 2.4 | 288 | 0.0 | 10 | 0.0 | 33 | 3.0 | 6 | 0.0 | 33 | 9.1 | 45 | 2.2 | 76 | 6.6 |
| Texas | 1981-83 | TX Parks & Wildl. Dept. 1982, 1983 | 1,405 | 12.0 | 1,347[c] | 29.5 | 73 | 2.7 | 569 | 0.7 | 518 | 1.0 | 2,633 | 14.3 | 858 | 0.9 | 325 | 2.8 | 198 | 4.5 | 39 | 12.8 | 299 | 22.4 | 404 | 24.8 | 820 | 23.4 |
| **Subtotal & Mean** | | | **11,092** | **2.6** | **-** | **-** | **165** | **2.4** | **998** | **0.5** | **873** | **0.8** | **3,248** | **12.0** | **1,343** | **0.7** | **528** | **1.9** | **231** | **4.3** | **45** | **11.1** | **332** | **21.1** | **449** | **22.5** | **1,156** | **18.3** |
| **Pacific** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nevada | 1974-77 | Barngrover 1977 | 1,388 | 9.1 | - | - | - | - | - | - | - | - | 1,460 | 8.4 | 412 | 0.2 | - | - | 29 | 0.0 | 349 | 17.5 | 509 | 17.7 | - | - | - | - |
| California | 1974-80 | Moore & King 1980 | 9,271 | 7.8 | - | - | - | - | 83 | 3.6 | 499 | 1.6 | 18,386 | 8.8 | 1,372[e] | 0.1 | - | - | 723 | 1.4 | - | - | - | - | - | - | - | - |
| Montana | 1976-81 | Childress 1985 | 2,467 | 2.4 | - | - | - | - | 1,140 | 0.4 | 510 | 0.8 | 687 | 1.9 | 363 | 0.0 | 592 | 2.4 | 550 | 0.2 | 141 | 9.2 | 99 | 4.0 | 19 | 0.0 | 505 | 3.2 |
| Oregon | 1974-83 | Vendshus n.d. | 3,212 | 21.3 | - | - | - | - | - | - | - | - | 2,981 | 25.2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Subtotal & Mean** | | | **16,338** | **9.7** | **-** | **-** | **-** | **-** | **1,223** | **0.7** | **1,009** | **1.2** | **23,514** | **10.6** | **2,147** | **1.4** | **592** | **2.4** | **1,302** | **0.8** | **490** | **15.1** | **608** | **15.5** | **19** | **0.0** | **505** | **3.2** |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Total & Mean*** | | | ***81,480*** | ***8.1*** | ***5,195*** [d] | ***8.8*** [d] | ***3,156*** | ***2.2*** | ***4,160*** | ***0.9*** | ***4,497*** | ***1.3*** | ***33,719*** | ***11.7*** | ***7,763*** | ***0.1*** | ***7,632*** | ***3.2*** | ***2,624*** | ***1.3*** | ***1,040*** | ***24.1*** | ***1,490*** | ***16.6*** | ***10,588*** | ***19.5*** | ***5,723*** | ***12.5*** |
| | | | | | ***2,612*** [c] | ***27.5*** [c] | | | | | | | | | | | | | | | | | | | | | | |
| **Grand total: 171,697 ducks examined; 8.9% of the gizzards had ≥1 shot.** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

[a]Number of gizzards examined.
[b]Percentage of gizzards with ≥1 shot.
[c]Mottled duck.
[d]Black duck.
[e]Teal, largely green-winged.

# Appendix Gamma

Contact Information for Alternative Weight Manufacturers

## Polyamide 6 Weights

LNP Plastics INC produced highly filled Polyamide 6 weight for Mercedes.

*Contact:*
Robert Russell, (610) 363-4500

## Steel Weights

The Japanese company AZUMA manufactures both adhesive and clip-on steel weights; the product name is Ironbond.

*Contact:*
http://home1.catvmics.ne.jp/~azuma/
http://www.gol.com/azuma
azwbw@gol.com

## Tin Weights

Tin clip-on weights are currently being produced by TRAX in the United Kingdom, in collaboration with the International Tin Research Institute (ITRI).

*Contact TRAX:*
www.traxadm.demon.co.uk
John Halle, +44 1938 554297; john_halle@traxadm.demon.co.uk

*Contact ITRI:*
www.itri.co.uk
Kay Nimmo, +44 1895 272406; kay@itri.co.uk

## ZAMA Weights

G. Introni & C. snc, Mr. Introini Alberto produce ZAMA weights from 5 to 50 g.

*Contact:*
Tel. 029834193 in Melegnano, Italy; g.introini@libero.it