

Five Chemicals Alternatives Assessment Study

Table 3.4.1 J: Assessment Summary – Alternatives for Lead Ammunition/ Shooting Ranges

Assessment Criteria		Lead (Reference)	Comparison Relative to Lead				
			Bismuth	Copper	Iron	Tungsten	Zinc
Technical/ Performance Criteria	Density	11.34 g/cm ³	-	-	-	+	-
	Frangibility	No	+	+	+	+	?
	Barrel Wear	Good	=	=	=	?	=
Environmental Criteria	Primary Drinking Water Standards (MCL Action Level)	15 µg/L	?	+	+	?	?
	Aquatic Toxicity: Water Quality Criteria (CMC)						
	Freshwater	65 µg/L	?	-	+	?	+
	Saltwater	210 µg/L	?	-	+	?	-
Human Health Criteria	Occupational Exposure: REL (8-hour TWA)	0.050 mg/m ³	?	+	+	+	+
	Carcinogenicity	EPA B2 IARC 2B	+	+	+	+	+
	Developmental Toxicity	Yes (Prop 65)	+	+	+	+	+
Cost	Cost/9mm round	\$0.14-\$0.20	-	-	-	-	-
	Operating Costs	High	+	+	+	+	+

Comparison Key + Better = Similar - Worse ? Unknown

3.4.2 Alternatives Assessment for Wheel Weights

Technical Assessment

Longevity/Life in Service

Wheel weights are installed on a vehicle's wheels during the tire balancing process and they typically remain in service until the tire is rebalanced or replaced, or until the wheel or vehicle is retired from use. Wheel weights are not typically reused so their life in service is determined by the frequency of tire rebalancing, the life of the tire and the life of the vehicle.

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Wheel weights do not typically wear out but they can “fly off” when a vehicle is jarred or during sudden velocity changes. Factors such as improper installation and damage from contact with curbs or other objects can also cause weights to fall off. It is estimated that the annual loss rate is 10%. (Root 2000)

None of the reports and studies reviewed suggested that the material used for the weights affected the life of the weights or was a factor in the rate that the weights fall off the wheels.

Key Standards for Component/End-product

Wheel weights must meet the vehicle manufacturers’ specifications before they can be used for Original Equipment Manufacturer (OEM) applications. OEM specifications can include the following: (Gearhart 2006b)

Corrosion protection: Corrosion protection is a focus of OEM specs. The OEMs typically require specs such as salt corrosion testing, cyclic corrosion testing, and UV testing for fading.

Physical dimensions: OEM specs limit maximum clearance dimensions (thickness, length, and width) to eliminate interference with other vehicle components and to prevent out-of-balance problems.

Shape: Some OEM specs specify shape properties such as curvatures or labeling surfaces.

Clip design: While the clip design is typically under producer control, the clip/weight assembly must meet specs such as clip gap and curl.

Material: OEMs did not specify the weight material in the past but they are beginning to specify lead-free weights.

Labeling: OEMs typically require labeling on wheel weights often including identification of the mass and material of the weight.

Aftermarket wheel weights are typically not required to meet OEM specifications.

Key Physical Characteristics & Performance Requirements

Density and Mass:

There are two common methods for attaching weights to wheels; clipping the weight to the rim of the wheel, and affixing the weight to the wheel using adhesive. For both wheel weight applications, a small weight size is desirable to prevent interference with other vehicle components, such as the brakes. Large weights are more visible and therefore less desirable, particularly for use on the outer rim of the wheel. Because density of the weight material directly influences the size of the wheel weight, it is a key physical characteristic.

All of the materials considered in this assessment are less dense than lead, which has a density of 11.34 g/cm³. With a density of 8.96 g/cm³, copper has the highest density of the alternatives in this assessment, followed by steel (7.87 g/cm³), tin (7.34 g/cm³), and zinc (7.10 g/cm³). (Automation Creations) The density of a zinc alloy (ZAMAC) used for wheel weights is 6.76 g/cm³. (Umicore)

The size (volume) of wheel weights made from copper, steel, tin and zinc must be larger than equivalent lead weights by 27%, 44%, 54%, and 60% respectively. Since the allowable thickness and width of wheel weights is limited, this increase in size is typically achieved by increasing the length of the weights. The mass of wheel weights used for passenger car applications typically ranges from 5 grams to 60 grams. (Hennessey Industries) Weights in this range are small enough that the increase

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in size (length) required for the alternative materials typically does not present problems. (Lohse, Sander & Wirts 2001)

Hardness:

Both clip-on weights and adhesive weights are mounted to curved surfaces of the wheel. Given the wide variety of wheel sizes and designs, it is desirable for wheel weights to be relatively soft and malleable so the curvature of the weight can be adjusted during installation to match the curvature of the wheel. (Lohse, Sander & Wirts 2001) Lead is a soft, malleable metal so it is relatively easy to make adjustments to the curvature of lead weights during installation with the use of a wheel weight hammer.

Lead has a hardness of 4.2 on the Brinell scale and a hardness of 1.5 on the Mohr's scale, which makes it softer than all of the alternative materials except pure tin. Pure tin has a Brinell hardness of 3.9 but some tin alloys are harder than lead (ASTM B 23 has a Brinell hardness of 17). The following table lists the wheel weight materials in order of increasing hardness: (Automation Creations)

Table 3.4.2 A: Hardness of Wheel Weight Materials

Material	Hardness		
	Brinell Scale	Mohr's Scale	Vickers Scale
Tin (pure)	3.9		
Lead	4.2	1.5	5
Tin (alloy)	17		
Zinc		2.5	30
Copper		3	50
ZAMAC (zinc alloy)	91		102
Steel (carbon)	170	5-6	

Malleability:

Copper, and tin are relatively malleable and the curvature of wheel weights made of these materials can be modified, to some degree, during installation. Zinc and zinc alloy are significantly harder and less malleable than lead so it may be difficult to adjust the curvature of the weights during installation. In addition to being relatively hard, steel has limited malleability and therefore forming of weights during installation to match the wheel diameter is typically not possible. The use of steel and zinc weights may require the number of standard wheel weight shapes to be increased. (Lohse, Sander & Wirts 2001)

Melting Point:

Heat generated during braking can result in brake disc temperatures of up to 1300 degrees F. The maximum temperature at the wheel rim where clip-on weights are installed is approximately 250 degrees F, while the maximum temperature at the wheel where adhesive weights are installed is typically well below 400 degrees F. (Lohse, Sander & Wirts 2001) The melting points for copper (1980 deg. F), steel (2732 deg. F), tin (450 deg. F) and zinc (787 deg. F) are higher than the

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maximum temperatures wheel weights are exposed to. The melting point of lead is 622 degrees F. (Automation Creations)

Corrosion Resistance:

Wheel weights must be corrosion resistant due to the harsh environment which includes exposure to moisture, high temperatures and road salt. The wheel weights must not undergo galvanic corrosion when affixed to steel or aluminum wheels. All lead weights used for OEM applications have a coating to prevent corrosion but many of the aftermarket lead weights are not coated. (Gearhart 2006a) Uncoated lead weights will leave black marks when applied to aluminum wheels.

Copper, steel and zinc wheel weights require a coating in order to prevent corrosion. Copper has good resistance to atmospheric corrosion but it develops a protective coating that over time thickens to give a green patina, which would be unacceptable for wheel weight applications. Steel weights will rust if they are not coated and zinc weights must be coated to prevent galvanic corrosion when mounted on aluminum wheels. A manufacturer of tin adhesive wheel weights states that no corrosion protection is required for tin wheel weights and that they will retain a good surface appearance. (Trax JH Ltd.)

Shape and Configuration:

It is advantageous for wheel weights to be malleable so they can be shaped during installation to match different wheel diameters. Using non-malleable materials for clip-on weights would result in the need to increase the number of shapes/styles/sizes to match the wide variety of wheel designs and sizes. The design of adhesive weights can be modified to account for the limited malleability of the materials like steel. Adhesive weights made of soft malleable materials can be in the form of a bar, while weights made of harder, less malleable materials are constructed of separate small weights attached to a strip of adhesive tape. Partitioning the weight into segments allows for application to the curved diameter of the wheel. (Lohse, Sander & Wirts 2001)

Recyclability:

Lead weights are collected for recycling after they are removed from wheels during the rebalancing of tires. The tire dealers and auto service stations that balance tires typically collect lead weights and send them to secondary smelters for recycling. EPA estimates that 16 million pounds of wheel weights are sent to secondary smelters. (USEPA 2005)

EPA estimates that an additional 8 million pounds may be processed in automobile recycling. During the recycling of automobiles, lead weights must be removed from the wheels to avoid contamination of recycled materials and auto shredder residue (ASR). (Ecology Center 2005a)

Lead from used wheel weights is also used by individuals who make their own lead fishing sinkers and ammunition, who collect the used weights from tire dealers and service stations. EPA estimates that 0.8 to 1.6 million anglers make their own fishing sinkers. This activity has the potential to expose individuals and family members to airborne lead particles or vapors released during the pouring of molten lead into the fishing sinker molds. (United States Environmental Protection Agency (USEPA) 1994)

All of the alternative materials considered in this assessment can also be recycled. Copper can be recycled without any loss of quality and the value of copper provides an economic incentive for recycling. The unique color and appearance of copper weights would facilitate material separation.

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Copper recovered from refined or re-melted scrap composed 30% of the total U.S. copper supply. (Edelstein 2006)

Steel is easily recycled and material separation may be easier with steel weights since they can be identified and sorted with the use of magnets. The clips for clip-on weights are also made of steel and therefore could be recycled along with the weight, eliminating the need for separation. Steel weights do not need to be removed from steel wheels during automobile recycling.

Tin and zinc weights resemble lead weights and are more difficult to sort and separate. The high cost of tin provides an economic incentive to recover weights for recycling. A German study estimated that, when vehicles are dismantled for recycling, tin weights would be removed from the vehicles' wheels at a rate approaching 100% because the high price of tin would justify this procedure. (Lohse, Sander & Wirts 2001)

There is the potential that the challenge of separating lead-free weights from lead weights will result in a decline in the recycling of all wheel weights. (Ecology Center 2005b)

The following tables provide additional technical performance data for each of the alternatives.

Table 3.4.2 B: Wheel Weights – Copper

Technical/ Performance Parameter	Measure/Metric	Source of Information
<i>Component/End-product</i>		
<u>Key</u> physical characteristics	<p>Density: The density of copper is 8.96 g/cm³ vs. 11.34 g/cm³ for lead, which means that, for a given weight size (mass), a copper weight will be 27% larger volume than a lead weight. (MatWeb)</p> <p>Melting Point: At 1980° F, the melting point of copper is significantly higher than the 622° F melting point of lead and well above the maximum operating temperatures required for wheel weights. (MatWeb)</p> <p>Corrosion resistance: Copper has good resistance to atmospheric corrosion. However, it develops a protective coating that over time thickens to give a green patina, which would be unacceptable for wheel weight applications. Therefore, copper weights require a protective coating. (Corrosion Doctors)</p> <p>A manufacturer of copper adhesive wheel weights states that its copper weights are coated to meet OE standards. (Trax)</p> <p>Malleability: Like lead, copper is very malleable.</p> <p>Hardness:</p> <p style="padding-left: 40px;">Annealed Copper, Vickers: 50 Lead, Brinell: 4.2 Lead, Vickers: 5</p> <p>(MatWeb)</p> <p>Recyclability – Copper can be recycled without any loss of quality. Copper recovered from refined or remelted scrap composes 30% of the total U.S. copper supply.</p>	<p>MatWeb, 2006</p> <p>Corrosion Doctors, 2006.</p> <p>Trax, 2006</p> <p>Edelstein, 2006.</p>

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Table 3.4.2 C: Wheel Weights – Steel

Technical/ Performance Parameter	Measure/Metric	Source of Information
<i>Component/End-product</i>		
<u>Key</u> physical characteristics	<p>Density: The density of steel is approximately 7.87 g/cm³ vs. 11.34 g/cm³ for lead, which means that, for a given weight size (mass), a steel weight will be 44% larger volume than a lead weight.</p> <p>Melting Point: At 2732° F, the melting point of steel is significantly higher than the 621° F melting point of lead and well above the maximum operating temperatures required for wheel weights.</p> <p>Corrosion resistance: Steel weights are subject to rusting and therefore must be coated for all wheel weight applications to prevent corrosion.</p> <p>Hardness:</p> <p style="padding-left: 40px;">Carbon steel, Brinell: 170 Lead, Brinell: 4.2 Lead, Vickers: 5</p> <p>Malleability: Steel has limited malleability and therefore forming of the weights during installation to match the wheel diameter is not possible.</p>	MatWeb, 2006

Table 3.4.2 D: Wheel Weights – Tin

Technical/ Performance Parameter	Measure/Metric	Source of Information
<i>Component/End-product</i>		
<u>Key</u> physical characteristics	<p>Density: The density of tin is 7.34 g/cm³ vs. 11.34 g/cm³ for lead, which means that, for a given weight size (mass), a tin weight will be 54% larger volume than a lead weight. (MatWeb)</p> <p>Melting Point: At 450° F, the melting point of tin is lower than the 622° F melting point of lead but it is above the maximum operating temperatures required for wheel weights. (MatWeb)</p> <p>Corrosion resistance: A manufacturer of tin adhesive wheel weights states that no corrosion protection is required for tin wheel weights and that they will retain a good surface appearance. (Trax)</p> <p>Hardness:</p> <p style="padding-left: 40px;">100% tin, Brinell: 3.9 tin alloy, ASTM B 23, Brinell: 17 Lead, Brinell: 4.2 Lead, Vickers: 5</p> <p>(MatWeb)</p>	<p>MatWeb, 2006</p> <p>Trax, 2006</p> <p>Sander, 2000</p>

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Table 3.4.2 D: Wheel Weights – Tin

Technical/ Performance Parameter	Measure/Metric	Source of Information
	Malleability: The malleability of tin is similar to lead. (Sander)	

Table 3.4.2 D: Wheel Weights – Zinc

Technical/ Performance Parameter	Measure/Metric	Source of Information
<i>Component/End-product</i>		
<u>Key physical characteristics</u>	<p>Density: The density of zinc is 7.10 g/cm³ vs. 11.34 g/cm³ for lead, which means that, for a given weight size (mass), a zinc weight will be 60% larger volume than a lead weight. (MatWeb)</p> <p>The density of zinc alloy ZAMAC ZL5 is 6.76 g/cm³. (Umicore)</p> <p>Melting Point: At 787° F, the melting point of zinc is significantly higher than the 622° F melting point of lead and well above the maximum operating temperatures for wheel weights. (MatWeb)</p> <p>Corrosion resistance: While zinc has good corrosion resistance, zinc wheel weights must be coated to prevent galvanic corrosion when mounted on aluminum wheels. (Umicore)</p> <p>Malleability: Zinc is malleable but is brittle at standard temperatures.</p> <p>Hardness:</p> <p style="padding-left: 40px;">Zinc, Vickers: 30 ZAMAC ZL5, Brinell: 91 (Umicore) ZAMAC ZL5, Vickers: 102 (Umicore) Lead, Brinell: 4.2 Lead, Vickers: 5</p> <p>(MatWeb)</p>	<p>MatWeb, 2006.</p> <p>Umicore, 2006.</p>

Financial Assessment

Initial Purchase Price for Chemical/Alternative

Lead is significantly less expensive than any of the alternatives in this assessment, with the exception of steel. In December 2005, the Platts Metals Week North American producer price for lead was \$0.65 per pound. The December 2005 price for copper (U.S. producer cathode) was \$2.23 per pound. For tin (Metals Week composite), the price was \$4.43 per pound, and for zinc (Platts Metals Week North American Special High Grade), the price was \$0.88 per pound. Steel is not traded on an exchange (e.g. London Metals Market) but the price for hot rolled steel plate, which was \$0.29 per pound in December 2005, suggests that the price of steel is competitive with lead. (Metals Consulting International (MCI))

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Initial Purchase Cost for End-product/Component

There are a variety of factors that affect the price of wheel weights including: material, weight, type, quantity in package, order size, vendor, and whether the weight is uncoated or coated. Wheel weights for passenger cars are available in a variety of weights, typically ranging from 0.18 oz. to 2.1 oz.

Clip-on wheel weights are available in a variety of different styles, where each style is designed to fit a specific wheel rim design. Wheel rim designs can vary by the vehicle year, make and model and wheel weight manufacturers often provide tire dealers with a chart that matches the wheel weight style to the vehicle.. The wheel weight styles are designated by letter codes such as AW, EN, FN, LH, and MC. “P” type weights are generic weights for passenger cars and “T” type weights are for trucks. (Hennessey Industries)

For lead weights, the most significant price factor appears to be the coating. A coated lead weight can cost 2-3 times more than the uncoated equivalent. This can be illustrated using prices from an online auto parts retailer, Patchboy.com. The price for an uncoated 0.25 oz. AW type lead weight was \$0.05, while the price for the coated version of the same weight was \$0.16. The price for an uncoated 2 oz. AW type lead weight was \$0.19, while the coated version of the same weight was \$0.38. By contrast, the difference in price between the various types of weights is minimal. For example, for 0.25 ounce coated lead weights, there is a \$0.01 difference between the AW type and the MC type. For the 2 ounce size, the prices for these two types are the same.

In a 2005 study, the Ecology Center of Ann Arbor, Michigan collected wheel weight price information from three retailers and three manufacturers located in North America, Europe and Japan. Price information was collected on clip-on lead weights (coated and uncoated) and clip-on coated steel and zinc weights. The Ecology Center made comparisons using the average price of weights from 0.25 – 2 oz. in size for each manufacturer and found that steel and zinc coated weights were comparable in price to lead coated weights. In some cases, lead-free weights could be purchased at a lower cost than high quality, coated lead weights. (Ecology Center 2005b)

The following table contains a cost comparison for lead, steel and zinc clip-on weights collected by the Ecology Center in 2005:

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Table 3.4.2 E: Wheel Weight Cost Comparison
Average Cost per Weight (for weight sizes 0.25 – 2 ounce)

Source: Ecology Center, 2005b

Wheel Weight Description	Source	Approximate Average Weight Cost
Lead, uncoated, P style	Retailer "B"	\$0.09
Steel, coated, P style	Manufacturer "E", Japan	\$0.15
Lead, uncoated, MC style	Retailer "A"	\$0.18
Zinc, coated, P style	Manufacturer "D", N. America	\$0.24
Lead, coated, MC style	Retailer "B"	\$0.25
Zinc, coated, MC style	Manufacturer "D", N. America	\$0.26
Lead, coated, MC style	Retailer "C"	\$0.29
Zinc, coated, MC style	Manufacturer "F", Europe	\$0.32
Zinc, coated, MC style	Manufacturer "E", N. America	\$0.38
Lead, coated, MC style	Retailer "A"	\$0.43

Copper weights are high quality coated weights and appear to be marketed to high end autos including Aston Martin. (Trax JH Ltd.) Although pricing was not available, it is expected that copper weights are significantly more expensive than lead weights based on raw material costs.

Pricing for tin weights was not available. It is expected that tin weights are significantly more expensive than lead weights based on raw material costs.

Availability of Chemical/Alternative

The Ecology Center of Ann Arbor, Michigan has estimated that 70,000 tons of lead is used each year to manufacture wheel weights worldwide. However, the quantity of lead used for this application is decreasing as auto manufacturers are switching to steel and zinc weights.

In 2005, the worldwide mine production of copper was 16.4 million tons but strong demand in China and India resulted in a global production deficit. In 2006, increased capacity is expected to result in a modest production surplus. (Edelstein 2006)

Global crude steel output in 2005 was 1,129 million metric tons. (Iron and Steel Statistics Bureau (ISSB)) Increased production of steel wheel weights is not expected to affect supply or price of steel.

In 2005, the U.S. consumption of tin was 51,480 tons. Tin has not been mined in the United States since 1993. During the period of 2001-2004, the primary sources of imported tin were Peru (44%), China (14%), Bolivia (14%), and Indonesia (11%). World tin reserves appear to be adequate to meet foreseeable demand. Domestic demand for primary tin is expected to grow slowly in the next few years, at a rate of about 1% per year. That rate, however, could double in a few years if new applications, especially those in which tin is substituted for toxic materials, such as lead-free solders, find acceptance in the marketplace. (Carlin, James F. Jr 2006)

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In 2005, there was a 200,000 ton production deficit of zinc worldwide. U.S. mine production in 2005 was 837,800 tons. Domestic zinc metal production capacity accounts for less than one-third of the quantity consumed domestically. Canada and Mexico are leading sources of zinc. (Gabby 2006)

Availability of Component/End-product

European and Japanese automobile manufacturers have switched to lead-free wheel weights and U.S. automobile manufacturers are currently in the process of making the switch. Most wheel weight manufacturers are now producing lead-free wheel weights to meet this demand. However, the aftermarket, which accounts for 80% of total wheel weight usage in the U.S., continues to use lead weights almost exclusively. (Gearhart 2006a) The following table lists the manufacturers known to produce lead-free wheel weights.

Table 3.4.2 F: Manufacturers of Lead-free Wheel Weights

Manufacturer	Country	Website	Type of Weight
Azuma	Japan	http://home1.catvmics.ne.jp/~azuma/	Steel
Banner GmbH	Austria	www.bannerbatterien.com	Steel, zinc
Dionys-Hoffman	Germany	www.dionys-hofmann.de	Zinc
Hennessy Industries, Inc. (Bada)	United States	www.ammcoats.com	Steel
Perfect Equipment	United States	www.perfectequipment.com	Steel, zinc
PCP Products	Thailand	www.pcpproductsinter.com	Zinc
Plombco	Canada	www.plombco.com	Zinc
Trax JH Ltd.	United Kingdom	www.traxjh.com	Copper, steel, tin, zinc

Copper adhesive weights are available from at least one major wheel weight manufacturer but copper clip-on weights are not available. Copper is not currently being used in the U.S. for wheel weights by either the auto manufacturers or the aftermarket.

Steel wheel weights are available in both clip-on and adhesive styles. Steel is less dense than lead and therefore steel weights are larger than lead weights. As a result, size restrictions limit the availability of some steel weights. Steel weights are available for passenger vehicles which typically use .25 - 2 ounce weights. Trucks often require larger weights which may not be available in steel.

General Motors and Ford are in the process of converting to steel weights and it is expected that this conversion will be complete in 2006 and 2007 respectively. Asian auto manufacturers are currently equipping most of their vehicles with steel weights. (Gearhart 2006b)

The availability of tin wheel weights is very limited. Only one manufacturer (Trax) was identified as a producer of tin wheel weights and only in the adhesive style.

Many of the leading manufacturers of wheel weights, including at least two in North America, produce both adhesive and clip-on zinc weights. Zinc weights are available in a variety of sizes and types but the zinc product offerings are typically not as extensive as the lead product offerings. Zinc

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weights are used extensively in Europe. U.S. auto manufacturers are equipping new vehicles exported to Europe with zinc weights. (Ecology Center 2005a)

Capital Costs

A significant investment in production equipment is required to start-up production of lead-free wheel weights. Many of the major wheel weight manufacturers have already added lead-free wheel weight production capacity to meet the demand for lead-free weights from the auto manufacturers. However, manufacturers that supply the U.S. aftermarket must still produce lead weights to meet the ongoing demand for inexpensive weights. A shift by the aftermarket to lead-free weights would likely require manufacturers to make additional investments in capital equipment.

It is not known what the current production capacity is for lead-free weights or the capital costs required to convert lead weight production to lead-free weight production. It is also not clear whether one type of lead-free weight production process is more capital intensive than another.

Key Operating Costs During Use of End-product

Operating costs for lead-free wheel weights are expected to be the same as for the equivalent lead weights. Whether the lead-free weights are clip-on or adhesive weights, they are installed in the same manner as the equivalent lead weights.

Replacement Rate

The replacement rate of wheel weights is dependent on a number of factors, including the rate at which weights are lost, and the frequency of tire replacement. It is estimated that 10% of installed wheel weights are lost on an annual basis and the average lifespan of a tire is three years or 44,000 miles. (Ecology Center 2005b)

Key End-of-Product Life Costs

Lead wheel weights that are removed from wheels during tire balancing are subject to state and federal hazardous waste rules unless they are recycled. The lead waste is typically recycled at secondary lead smelters. The lead weights must be transported by licensed haulers, usually those that transport lead acid batteries. The removal and storage of lead weights for recycling may require special containers and recordkeeping. (Minnesota Pollution Control Agency (MPCA) 1998)

If lead weights are not removed from automobiles prior to automobile recycling and shredding, lead can contaminate other recyclable materials and the auto shredder residue (ASR). ASR contaminated with lead may be classified as hazardous waste. (Ecology Center 2005a)

Used copper, steel, tin and zinc wheel weights are not subject to state and federal hazardous waste rules and therefore waste management and recycling costs may be reduced. Steel, copper and zinc are widely used in automobiles so weights made from these materials are not likely to become contaminants in the automobile recycling process since they are recovered during the recycling process. The high value of scrap copper and tin provides an economic incentive for recovery and recycling.

The following tables provide additional financial data for each of the alternatives.

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Table 3.4.2 G: Wheel Weights – Copper

Financial Parameter	Measure/Metric	Source of Information
<i>Required Data</i>		
Initial purchase price for chemical/alternative	Copper raw material price: \$2.23 per pound, U.S. producer cathode, December 2005 Lead raw material price: \$0.65 per pound, Platts Metals Week North American producer price, December 2005	Edelstein, 2006 Gabby, 2006a
Initial purchase cost for end-product/component	Copper weights are high quality weights with small size and appear to be marketed to high end autos including Aston Martin and although pricing was not available, it is expected that copper weights are significantly more expensive than lead weights.	Trax, 2006
Availability of chemical/alternative	In 2005, the worldwide mine production of copper was 16.4 million tons but strong growth in China and India resulted in a global production deficit. In 2006, increased capacity is expected to result in a modest production surplus. It is estimated that 70,000 tons of lead are used per year to manufacture wheel weights worldwide.	Edelstein, 2006 Ecology Center, 2006
Availability of component/end-product	Copper adhesive weights are available from at least one major wheel weight manufacturer. Copper is not currently being used in the U.S. for wheel weights by either the auto manufacturers or the aftermarket. The aftermarket, which accounts for 80% of wheel weight usage in the U.S., continues to use lead weights almost exclusively.	Trax, 2006 Gearhart, 2006a
<i>Additional Data if Available</i>		
Key operating costs during use of end-product	Operation costs for copper weights are expected to be the same as for other adhesive weights. Copper adhesive weights are installed in the same manor as other adhesive weights.	
Key end-of-product life costs	Copper can be recycled without any loss of quality and 30% of U.S. demand is met by recycled copper. The price of copper provides an economic incentive to recycle scrap copper and it is expected that businesses that balance tires would recycle many of the copper weights removed from wheels. Identification of copper weights is not expected to be an issue since the weights are typically labeled and their copper color is unique.	Edelstein, 2006

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Table 3.4.2 H: Wheel Weights – Steel		
Financial Parameter	Measure/Metric	Source of Information
<i>Required Data</i>		
Initial purchase price for chemical/alternative	The price for hot rolled steel plate in Dec 2005 was approximately \$0.29/lb. Lead raw material price: \$0.65 per pound, Platts Metals Week North American producer price, December 2005	steelonthenet, 2006 Gabby, 2006a
Initial purchase cost for end-product/component	All steel wheel weights are coated. Steel clip-on weights are comparable in price to coated lead clip-on weights and in some cases they are lower in price. The average price for P style steel weights (0.25 – 2 oz.) from a Japanese manufacturer was \$0.15.	Ecology Center, 2005b
Availability of chemical/alternative	Global crude steel output in 2005 was 1,129 million metric ton. Increased production of steel wheel weights will not affect supply or price of steel. It is estimated that 70,000 tons of lead are used per year to manufacture wheel weights worldwide.	ISSB, 2006 Ecology Center, 2006
Availability of component/end-product	Steel wheel weights are available in both clip-on and adhesive styles. Steel is less dense than lead and therefore steel weights are larger than lead weights. As a result, size restrictions limit the availability of some steel weights. Steel weights are available for passenger vehicles which typically use .25 - 2 ounce weights. Trucks often require larger weights which may not be available in steel. General Motors and Ford are in the process of converting to steel weights and it is expected that this conversion will be complete in 2006 and 2007 respectively. Asian auto manufacturers are currently equipping most of their vehicles with steel weights. In the U.S., the aftermarket, which accounts for 80% of wheel weight usage, continues to use lead weights almost exclusively.	Gearhart, 2006a
<i>Additional Data if Available</i>		
Key operating costs during use of end-product	Operation costs for steel weights are expected to be the same as for the equivalent lead weights since steel weights are installed in the same manor as lead weights.	
Key end-of-product life costs	Used steel wheel weights are not subject to state and federal hazardous waste rules and therefore waste management and recycling costs may be reduced. Steel is widely used in automobiles so weights made from this material is not likely to become a contaminant in the automobile recycling process since it is recovered during the recycling process.	

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Table 3.4.2 I: Wheel Weights – Tin		
Financial Parameter	Measure/Metric	Source of Information
<i>Required Data</i>		
Initial purchase price for chemical/alternative	<p>Tin raw material price: \$4.43 per pound, Metals Week composite, December 2005</p> <p>Lead raw material price: \$0.65 per pound, Platts Metals Week North American producer price, December 2005</p>	<p>Carlin, 2006b</p> <p>Gabby, 2006a</p>
Initial purchase cost for end-product/component	Pricing for tin weights was not available. It is expected that tin weights are significantly more expensive than lead weights.	
Availability of chemical/alternative	<p>In 2005, the U.S. consumption of tin was 51,480 tons. Tin has not been mined in the United States since 1993. World tin reserves appear to be adequate to meet foreseeable demand.</p> <p>Domestic demand for primary tin is expected to grow slowly in the next few years, at a rate of about 1% per year. That rate, however, could double in a few years if new applications—especially those in which tin is substituted for toxic materials, such as lead-free solders - find acceptance in the marketplace.</p> <p>Recycling: About 9,000 tons of tin from old and new scrap was recycled in 2005. Of this, about 5,000 tons was recovered from old scrap at 2 detinning plants and 91 secondary nonferrous metal processing plants.</p> <p>Import Sources (2001-04): Peru, 44%; China, 14%; Bolivia, 14%; Indonesia, 11%; and other, 17%.</p> <p>It is estimated that 70,000 tons of lead are used per year to manufacture wheel weights worldwide.</p>	<p>Carlin, 2006b</p> <p>Ecology Center, 2006</p>
Availability of component/end-product	<p>Availability of tin wheel weights was very limited.</p> <p>In the U.S., the aftermarket, which accounts for 80% of wheel weight usage, continues to use lead weights almost exclusively.</p>	Gearhart, 2006a
<i>Additional Data if Available</i>		
Key operating costs during use of end-product	Operation costs for tin weights are expected to be the same as for the equivalent lead weights since tin weights are installed in the same manor as lead weights.	
Key end-of-product life costs	Used tin wheel weights are not subject to state and federal hazardous waste rules and therefore waste management and recycling costs may be reduced. The high value of scrap tin provides an economic incentive for recovery and recycling.	

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Table 3.4.2 J: Wheel Weights – Zinc		
Financial Parameter	Measure/Metric	Source of Information
<i>Required Data</i>		
Initial purchase price for chemical/alternative	Zinc raw material price: \$0.88 per pound, Platts Metals Week North American Special High Grade, December 2005 Lead raw material price: \$0.65 per pound, Platts Metals Week North American producer price, December 2005	Gabby, 2006b Gabby, 2006a
Initial purchase cost for end-product/component	Coated zinc clip-on weights are comparable in price to coated lead clip-on weights. The average price for zinc weights (0.25 – 2 oz.) from a N. American manufacturer was approximately \$0.24 for P style weights and \$0.26 for MC style weights.	Ecology Center, 2005b
Availability of chemical/alternative	U.S. mine production in 2005 was 837,800 tons. Domestic zinc metal production capacity accounts for less than one-third of quantity consumed domestically. Canada and Mexico are leading sources of zinc. In 2005, there was a 200,000 ton production deficit worldwide. It is estimated that 70,000 tons of lead are used per year to manufacture wheel weights worldwide.	Gabby, 2006b Ecology Center, 2006
Availability of component/end-product	Many of the leading manufacturers of wheel weights, including at least two in N. America, produce zinc weights. Zinc weights are available in a variety of sizes and types but the manufacturers zinc product offerings are typically not as extensive as their lead product offerings. Zinc weights are used extensively in Europe. U.S. auto manufacturers are equipping new vehicles exported to Europe with zinc weights. In the U.S., the aftermarket, which accounts for 80% of wheel weight usage, continues to use lead weights almost exclusively.	Ecology, 2006 Gearhart, 2006a
<i>Additional Data if Available</i>		
Key operating costs during use of end-product	Operation costs for zinc weights are expected to be the same as for the equivalent lead weights since zinc weights are installed in the same manor as lead weights.	
Key end-of-product life costs	Used zinc wheel weights are not subject to state and federal hazardous waste rules and therefore waste management and recycling costs may be reduced. Zinc is widely used in automobiles so weights made from this material is not likely to	

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Table 3.4.2 J: Wheel Weights – Zinc			
	Financial Parameter	Measure/Metric	Source of Information
		become a contaminant in the automobile recycling process since it is recovered during the recycling process.	

Environmental Assessment

EPA estimates that 50 to 60 million pounds of lead are used each year to produce wheel weights in the United States. (United States Environmental Protection Agency (USEPA) 2005) In a 2003 study of the stocks and flows of lead wheel weights in the U.S., the U.S. Geological Survey (USGS) reported that approximately 56 million pounds of lead were used to produce wheel weights and approximately 130 million pounds of lead weights were in use on registered vehicles (Bleiwas, 2006). This USGS study estimated that 4 million pounds of lead wheel weights were lost on U.S. roadways in 2003 and an additional 8 million pounds were unaccounted for. The study also estimated that 75 percent (28 million pounds) of lead weights removed from vehicles by tire retailers, repair shops and dealerships were recycled and 6 million pounds of lead wheel weights were recycled by automotive scrap dealers in 2003.

A study published in 2000 estimated that the fleet of cars and light trucks currently in operation in the U.S. contain 55 million pounds of lead wheel weights. (Root 2000) Root estimated that 10% of these weights (5.5 million pounds) fall off the vehicles each year with 3.3 million pounds being deposited on urban streets where much of it is ground into dust by automobile traffic. The study claimed that the residual lead dust can then be washed into waterways or sewers, migrate into nearby residential properties, or become airborne particulates. Wheel weights are also collected during street cleaning operations and then disposed of in municipal landfills.

Drinking Water Standards

The fate of wheel weights that fall off during use is not fully understood but the potential for wheel weight materials to contaminate groundwater, including drinking water supplies, exists. Some of the wheel weights that are deposited on streets and highways are collected by street cleaning operations and disposed of in municipal landfills. The acidic conditions in the municipal landfills can solubilize lead from the wheel weights, resulting in lead contamination of groundwater. (United States Environmental Protection Agency (USEPA))

The National Primary Drinking Water Regulations are legally enforceable standards, set by EPA, that apply to public water systems. In these standards, the Maximum Concentration Level (MCL) for lead in drinking water is 15 $\mu\text{g}/\text{L}$ and the Maximum Concentration Level Goal (MCLG) is zero. Copper is the only alternative wheel weight material in this assessment for which EPA has set an MCL. Copper has an MCL of 1300 $\mu\text{g}/\text{L}$.

EPA has also established National Secondary Drinking Water Standards, which are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The following list shows the alternative wheel weight materials included in these secondary standards (aluminum is used in the zinc alloy ZAMAC):

- Copper: 1000 $\mu\text{g}/\text{l}$
- Iron: 300 $\mu\text{g}/\text{l}$

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- Zinc: 5000 µg/l
- Aluminum: 20-500 µg/l

Florida and Minnesota have established maximum concentration levels for tin in drinking water (4200 µg/l and 4000 µg/l respectively). Arizona set the maximum concentration level for copper at 1300 µg/l.

Affinity for Water: Water Solubility

Lead, copper, steel and tin are insoluble in water. Zinc is soluble in water but the solubility is dependent on the properties of the water, such as acidity, temperature, chlorine concentration and hardness. It should be noted that certain compounds of these metals may be soluble.

Density

All of the materials considered in this assessment are less dense than lead, which has a density of 11.34 g/cm³. With a density of 8.96 g/cm³, copper has the highest density of the alternatives in this assessment, followed by steel (7.87 g/cm³), tin (7.34 g/cm³), and zinc (7.10 g/cm³). (Automation Creations) The density of a zinc alloy (ZAMAC) used for wheel weights is 6.76 g/cm³. (Umicore)

Bioaccumulation

According to the International Chemical Safety Cards (ICSCs), bioaccumulation of lead may occur in plants and mammals and it is strongly advised that lead does not enter the environment. Specific information on the bioaccumulation of copper, steel, tin, and zinc were not available. As discussed earlier in this report, EPA is in the process of developing a framework that will address the issue of bioaccumulation of metals, as well as related issues such as bioavailability.

Aquatic toxicity

National Recommended Water Quality Criteria was used as a source for data on aquatic toxicity of lead and lead-free alternatives. Water Quality Criteria includes the following two aquatic life criteria for both freshwater and saltwater:

- Criteria Maximum Concentration (CMC) – An estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.
- Criteria Continuous Concentration (CCC) – An estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

Lead, copper and zinc are listed as Priority Toxic Pollutants and iron is listed as a Non Priority Pollutant. Tin was not included in the Water Quality Criteria list. The following table shows the Water Quality Criteria for lead, copper, iron and zinc.

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Table 3.4.2 K: Water Quality Criteria

Priority Pollutant	Freshwater		Saltwater	
	CMC ($\mu\text{g/L}$)	CCC ($\mu\text{g/L}$)	CMC ($\mu\text{g/L}$)	CCC ($\mu\text{g/L}$)
Lead	65	2.5	210	8.1
Copper	13	9.0	4.8	3.1
Iron	-	1000	-	-
Zinc	120	120	90	81

The Water Quality Criteria values indicate that lead, copper and zinc are toxic to aquatic organisms, even at relatively low concentrations. Of the wheel weight materials considered in this assessment, tin and steel appear to be the least toxic to aquatic organisms.

In 1994, EPA addressed the aquatic toxicity of alternatives to lead fishing sinkers in its response to citizens' petition and proposed ban for lead fishing sinkers. In its assessment of aquatic toxicity of lead alternatives, EPA made the following statements about copper, tin and zinc: "Laboratory studies indicate that copper is more toxic to aquatic organisms, such as fish, crustaceans, worms, and algae than lead." (United States Environmental Protection Agency (USEPA) 1994) However, EPA believes that environmental conditions in freshwaters would mitigate the toxicity of copper to aquatic organisms. "Tin, in the inorganic form, is generally much less toxic to aquatic organisms (crustaceans and fish) than lead because of its low solubility, poor absorption, low uptake rate, and rapid excretion." Zinc is more toxic to aquatic organisms (fish and crustaceans) than lead and it may be more bioavailable to aquatic organisms than lead. Information about the aquatic toxicity of steel was not found.

Human Health Assessment

Acute Human Effects

Occupational Exposure Limits

IDLH

The Immediately Dangerous to Life or Health Concentrations (IDLH) for lead is 100 mg/m^3 . The IDLH for copper and tin is also 100 mg/m^3 . Data on the IDLH for steel and zinc were not located. For iron, 1-2 grams may cause death but 2-10 is usually ingested in fatal cases.

PEL

The Permissible Exposure Level (PEL) for lead is 0.050 mg/m^3 (8-hour TWA). The PEL (TWA) for copper is 1 mg/m^3 ; for tin it is 2 mg/m^3 ; and for aluminum (in zinc alloy ZAMAC) it is 15 mg/m^3 . PELs have not been established for steel and zinc; however, PELs have been set for zinc chloride (1 mg/m^3) and zinc oxide (5 mg/m^3).

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REL

The Recommended Exposure Level (REL) for lead is 0.050 mg/m³ (TWA). The REL (TWA) for copper is 1 mg/m³; for steel (iron) it is 1 mg/m³; for tin it is 2 mg/m³; and for aluminum (in zinc alloy ZAMAC) it is 10 mg/m³ (total). An REL has not been established for zinc.

Irritation

Dermal

Lead does not cause dermal irritation. Skin exposure to copper, steel (iron), tin and zinc may cause dermal irritation.

Ocular

Dusts of lead and all of the lead-free alternatives can cause ocular irritation, with the exception of zinc.

Respiratory

Dusts of lead and zinc were not identified as respiratory irritants, while copper, steel (iron) and tin can cause respiratory irritation.

Chronic Human Effects

Mutagenicity and Carcinogenicity

Lead is classified as both a mutagen and probable human carcinogen (IARC 2B). The lead-free alternatives in this assessment (copper, steel, tin and zinc) are not classified as either mutagens or carcinogens.

Reproductive and Developmental Toxicity

Lead has been identified as a developmental toxicant in humans. Children are particularly sensitive to the chronic effects, which include slowed cognitive development and reduced growth. High lead exposure is also associated with reproductive effects, such as decreased sperm count in men, spontaneous abortions in women and low birth weight (USEPA).

The lead-free alternatives in this assessment (copper, steel, tin and zinc) have not been identified as reproductive or developmental toxicants.

Assessment Summary

The following is a summary of the alternatives assessment data for lead wheel weights.

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Table 3.4.2 L: Assessment Summary Alternatives for Lead Wheel Weights

Assessment Criteria		Lead (Reference)	Comparison Relative to Lead			
			Copper	Steel	Tin	Zinc
Technical/ Performance Criteria	Density	11.34 g/cm ³	-	-	-	-
	Malleability	Good	=	-	=	-
	Corrosion Resistance (with coating)	Good	=	=	+	=
Environmental Criteria	Primary Drinking Water Standards (MCL Action Level)	15 µg/l	+	+	+	?
	Aquatic Toxicity: Water Quality Criteria (CMC)					
	Freshwater Saltwater	65 µg/L 210 µg/L	- -	+ (iron) ?	? ?	+ -
Human Health Criteria	Carcinogenicity	EPA B2 IARC 2B	+	+	+	+
	Developmental Toxicity	Yes (Prop 65)	+	+	+	+
	Occupational Exposure: REL (8-hour TWA)	0.050 mg/m ³	+	+	+	+
Cost	Price per weight (coated, ¼ – 2 oz)	\$0.25 - \$0.43	-	= / +	-	=
	Available in clip-on & adhesive styles	Yes	-	=	-	=
	End-of-Life Cost (Auto Shredder)	Average	+	+	+	+

Comparison Key + Better = Similar - Worse ? Unknown

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3.4.3 Alternatives Assessment for Fishing Sinkers

Technical Assessment

Longevity/Life in Service

The primary factor affecting the life in service of fishing sinkers is the frequency that they are lost during use. Fishing sinkers of all types are lost during use, such as when the sinker becomes caught on weeds, rocks or other objects. Fishing sinkers can also come loose during casting if they are not properly secured.

Fishing sinkers do not typically wear out. A review of literature on fishing sinkers in the environment, as well as fishing sinker manufacturers' and retailers' websites and brochures, did not identify any data about the service life of fishing sinkers or the effect that the materials of construction have on the service life.

Key Standards for Component/End-product

In efforts to protect water birds from lead poisoning from fishing sinkers, the following northeastern states have enacted legislation restricting the use and/or sale of certain lead fishing sinkers (Minnesota Office of Environmental Assistance (MOEA)):