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Introduction

Lead is used in many widely known applications, such as automobile batteries and radiation shielding. Another lesser known, but long-term, use of lead is in automotive vehicle wheel weights (fig. 1). Lead weights have been used to balance wheels since the 1930s (Mike Astorino, Vice President of Sales and Marketing, Perfect Equipment Incorporated, oral commun., July 26, 2005) because of its high specific gravity, low relative cost, and its malleability. Out-of-balance tires tend to "cup" and vibrate and as a result cause excessive wear on tires and vehicle suspension components and result in compromised handling, especially at high speeds. The mass, number, and style of weights needed to balance a wheel depend on the tire's size and weight and on the type and condition of the wheels (rims) on the vehicle.

Figure 1. Six-ounce clip-on and 6-ounce adhesive-backed lead weights for use on larger vehicles, such as buses and trucks (photo source: Donald I. Bleiwas).

This study addresses an accounting of the stocks and flows of lead contained in lead wheel weights from their manufacture, through use, dissipation, and recycling, and environmental issues associated with the use of lead.

Environmental Concerns Associated With Lead Wheel Weights

The United States Environmental Protection Agency (EPA) recognizes the dangers of lead to the environment and human health, in general (U.S. Environmental Protection Agency, 2005a, b) and has created regulations in the United States that ban the use of lead in some products, such as lead-based paint in the late 1970s and leaded fuels for vehicles in the early 1980s. More recently, the EPA recognized that lead-based wheel weights that have fallen from vehicles and unaccounted lead weights that do not enter the recycling stream may be potential contributors of lead to the environment (U.S. Environmental Protection Agency, 2005c) and may require further investigation following denial of a petition submitted to the Agency by the Ecology Center to ban their use, on the grounds that more research is required.

As of July 1, 2005, lead wheel weights were banned on new vehicles and on after-market wheels in Europe in response to environmental concerns about losses along roadways and inappropriate disposal by tire retailers and scrap processors (Tin Technology, 2003; Perfect Equipment, 2005). European-manufactured vehicles are using steel, zinc, and other metals as a substitute for lead in wheel weights. American manufacturers are also producing zinc weights as a replacement for lead (Perfect Equipment, 2005).

Although there are no Federal regulatory controls governing the use of lead wheel weights in the United States (U.S. Environmental Protection Agency, 2005c), actions at state levels of government, sometimes in response to non-government organizations reflect concerns similar to those of governments in Europe. The State of Minnesota and the city of Ann Arbor, Michigan are phasing out the use of lead wheel weights on their fleet vehicles (Ecology Center, 2004; Minnesota Department of Administration, 2004). In Washington State, some tire and wheel retailers are voluntarily switching to zinc wheel weights that do not contain lead. The replacement weights are being supplied at no cost to the retailers through a grant partially funded by the EPA (Ecology Center, 2005a).

It is unclear whether substitute materials are neutral in their environmental impacts. For example, several studies on examining zinc released into the environment, from tire wear

(tire rubber contains zinc) and from other sources, have indicated that there may be some environmental consequences that require further study (Councell and others, 2004; Minnesota Department of Administration, 2004).

Analysis of Stocks and Flows of Lead Wheel Weights

The potentially toxic affects of lead in the environment and potential changes to its use brought about by legislation and material substitution suggests that an understanding of the metal's use is important. The lead used in wheel weights is best understood in the broader context of the stocks and flows (amount and nature of materials in use, losses and recovery, and reuse through recycling) of lead use in the economy.

Virtually all wheel-weight lead, actually an alloy containing approximately 5 percent antimony, is recovered from recycled automobile batteries. It is continually added to the total lead stocks in use through the sales of new vehicles and with the maintenance and replacement of worn tires on older vehicles. At the same time, lead is taken out of stocks in use by other processes, such as loss of weights on roads, removing wheel weights when tires are replaced, and scrapping old or damaged vehicles. Over the last few years, the importation of new vehicles that have wheel weights using materials other than lead also works to limit the amount of lead entering the cycle.

Figure 2 is a generalized representation of stocks and flows of lead wheel weights in the United States for the year 2003. Values are expressed as metric tons (t) of lead contained in wheel weights. Tonnages associated with the stocks and flows should be considered as estimates; few statistics are published and assumptions were incorporated into developing the estimates that can be revised should additional information become available. Estimates are rounded to the nearest thousand tons of contained lead.

Manufacture and Trade

The U.S. Geological Survey reported that approximately 28,000 t of lead was used in the production of wheel weights in the United States in 2003 (fig. 2) (Smith, 2005; Peter Gabby, lead commodity specialist, U.S. Geological Survey, oral commun., April 12, 2006).

There is some trade in lead wheel weights with Canada and Mexico. The high weight and low value of lead wheel weights preclude significant amounts of overseas imports or exported wheel weights. It was estimated that approximately 4,000 t were imported from Canada in 2003 (Peter Gabby, lead commodity specialist, U.S. Geological Survey, oral commun., April 7, 2006).

Use of these weights was by fleet managers, tire dealers, vehicle manufacturers, and others in the United States and was added to the stock of lead wheel weights in use. Lead weights are also held in inventory by manufacturers, tire retailers, and installed on unregistered vehicles. Movement to and from inventories is difficult to estimate because of individual company policies, new car sales, rate of tire replacement, new store openings and other factors.

Initial Distribution and Inventories

Wheel weights enter use primarily through commercial repair shops (including vehicle dealerships), fleet management facilities, tire retailers, and vehicle manufacturers.

The amount of weights used for tire repair and replacement and inventories was estimated at approximately 22,000 t of lead in weights. Inventories are on-the-shelf material and are replenished on an as-needed basis. The construction of new stores also requires establishing an initial inventory. Inventories of lead weights were estimated to be unusually high in 2003 at 8,000 t, primarily due to an increase in imports from Canada (Peter Gabby, lead commodity specialist, U.S. Geological Survey, oral commun., April 12, 2006). Inventory estimates are based on interviews performed by the author from a sample of the 12 largest retail tire store chains in the United States and provided from other sources (Mike Astorino, Vice President of Sales and Marketing, Perfect Equipment Incorporated, oral commun., April 1, 2006; Peter Gabby, lead commodity specialist, U.S. Geological Survey, oral commun., April 7, 2006). Six thousand tons of this estimate was assigned to a category containing tire retailers and repair shops, and other holders of inventory. About 2,000 t may have been held in inventory by vehicle manufacturers.

The movements to and from inventories was difficult to estimate because of company policies, new car sales, rate of tire replacement, new store openings and other factors.

Based on the number of new vehicles produced and sold in the United States in 2003, it was estimated that approximately 10,000 t of lead in wheel weights was used.

Lead Wheel-Weights in Use

In 2003, approximately 65,000 t of lead wheel weights were estimated to be in use on 232 million registered automobiles, light trucks, and commercial vehicles (U.S. Federal Highway Administration, 2006). This figure was derived using an estimate of 2.5 ounces of lead wheel weights per wheel for automobiles and light trucks and 7 ounces for each front wheel (weight on other wheels is considered insignificant) for large commercial vehicles (Carlton Freeman, Supervisory Engineer, Bada Division of Hennessy Industries, oral commun., July 26, 2005; Mike Astorino, Vice President of Sales and Marketing, Perfect Equipment Incorporated, oral commun., July 26, 2005; Jeff Gearheart, Campaign Director, Ecology Center, oral commun., August 11, 2003). For automobiles and light trucks, it was assumed that 80 percent of

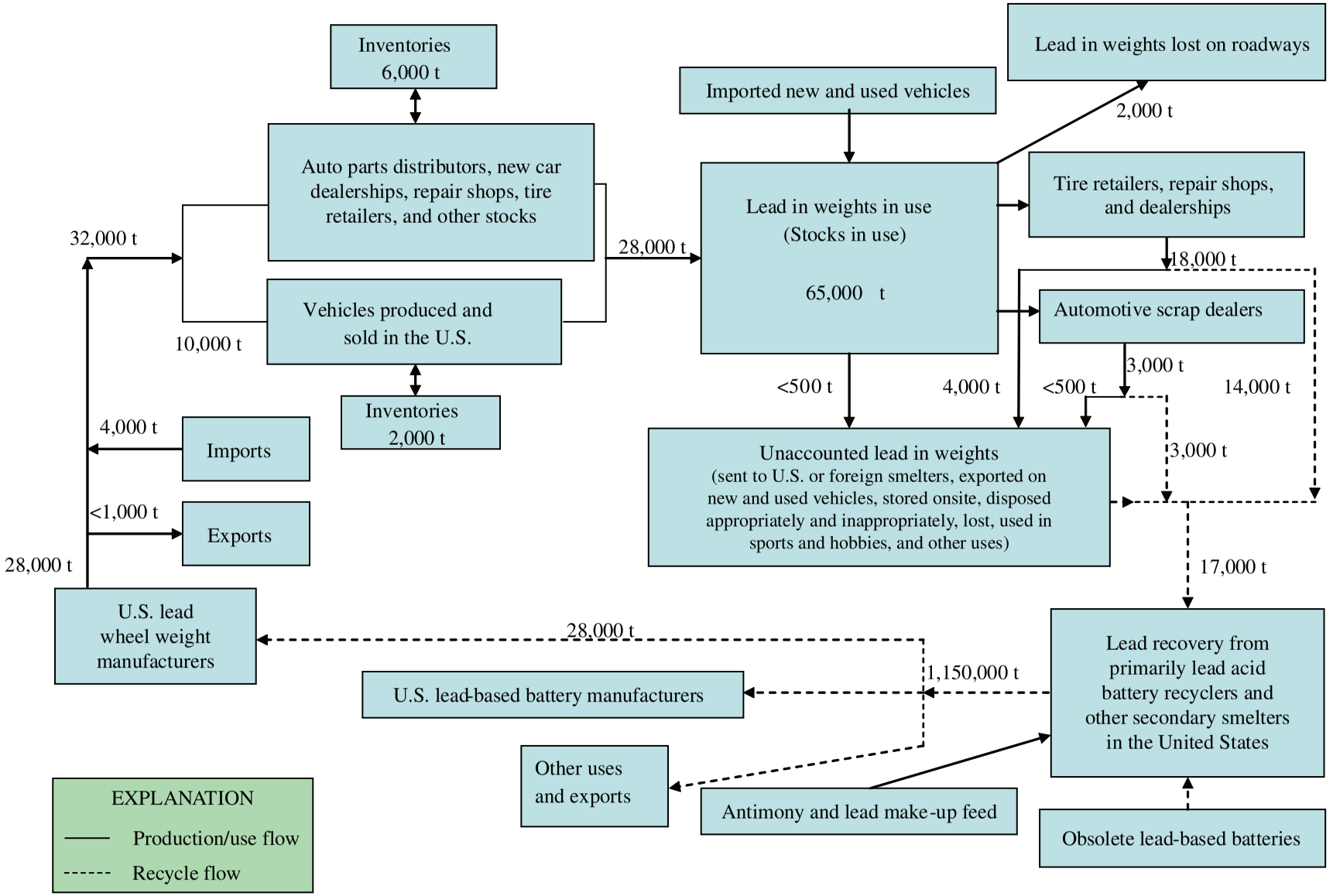

Figure 2. A generalized representation of stocks and flows of lead-based wheel weights in the United States (2003).

vehicles had weights. This 80 percent factor was considered a reasonable assumption to accommodate recently imported vehicles that do not use lead weights and vehicles that, for one or more reasons, may be missing or not using wheel weights.

The total amount of lead in stock in use as wheel weights on vehicles in the United States may differ from year to year because of the addition of new vehicles, the rate of the retirement (scrapped) of vehicles, rate of tire replacement, greater or lesser use of material substitution and newer wheel-balancing technology, and wheel weight loss from vehicles in use. Although not considered significant, exported vehicles with weights mounted on the wheels also contribute to a loss of stocks in use. Likewise, the number of imported vehicles with lead wheel weights is also considered insignificant, especially owing to the fact that some countries now ban their use (Tin Technology, 2003; Perfect Equipment, 2005). Beginning in 2006, some domestically produced vehicles will use lead-free wheel weights in order to permit export to Europe and possibly in anticipation of a ruling banning the material from use. The substitution of other materials for lead will affect future stocks in use dramatically, especially if tire retailers change to the use of non-lead-based wheel weights.

Lead Wheel Weights Lost on Roadways During Use

In 2003, it was estimated approximately 2,000 t of lead in wheel weights in use were lost on the Nation's roadways. An estimate of nearly 5,000 t was estimated by the Ecology Center using different estimation criteria (Ecology Center, 2005b) in early 2005, but the estimate by the Center was reduced to 1,600 t in a subsequent publication (Ecology Center, 2005c). Most weights are lost on urban roads where hitting curbs and potholes, rapid acceleration and decelerations, and sharp turning can cause clip-on weights and poorly applied adhesive-backed weights to come loose. Often, lost weights drop to the road surface where they may become abraded by vehicle traffic (fig. 3), eventually becoming dissipated into the environment by wind and storm water (Root, 2000; Robert Root, senior research scientist, Battelle Memorial Institute, retired, oral commun., 2005).

In regards to lead in the environment, the antimony content of the wheel weight could be a useful indicator in distinguishing this source of lead from other possible sources, such as from the legacy of leaded gasoline. Because lead wheel weights have been used on vehicles for about 70 years, the cumulative amount of contained lead dispersed may be significant.

Recovery from Tire Replacement, Repairs, and Automotive Scrap

Approximately 268 million new and retreaded automobile, light truck, and heavy commercial-truck replacement tires were sold in 2003 (Rubber Manufacturers Association, 2005). Using this data, along with assumptions about weight per wheel described above, about 18,000 t of lead in lead wheel weights were recovered from tire replacements. This estimate includes an adjustment to accommodate tires that had lost weights during use and were not collected, and additional weights collected from tire repair. The re-use of wheel weights by retailers, a practice of some retail tire stores, was not considered significant and therefore not included in the estimate.

Figure 3. Clip-on 1-ounce lead-based wheel weights; comparison of a new weight and one abraded by traffic (photo source: Donald I. Bleiwas).

Based on the number of automobiles, light trucks and SUVs scrapped in 2003 (Bureau of Transportation Statistics, 2006), an estimated 3,000 t of lead in wheel weights was recovered by automotive scrap dealers. Scrapped commercial truck data are not available, and probably amounted to less than 500 t. Most of the lead weights collected by scrap dealers are assumed to be sent to domestic or foreign secondary lead smelters which also treat lead from obsolete lead-acid vehicle batteries. In 2003, secondary smelting facilities produced approximately 1.15 million tons (Mt) of lead, of which approximately 92 percent was from vehicle batteries.

An informal survey determined that about half of tire retailers and fleet managers recycle lead wheel weights (MacDicken, 2005) by selling them either directly to smelters

or through dealers. This does not suggest that only half of the weights are recycled, since most of the country's replacement tires are sold through large tire chain retails. The Nation's largest retail tire store chains such as Bridgestone/Firestone, Discount Tire Co. (R. Woolford, Executive Assistant, Discount Tire Company, oral commun., February 7, 2006), Les Schwab, Sears (Sears Holding Corp.), and Wal-Mart (M. Rojo, Store Manager, Wal-Mart, oral commun., February 7, 2006) have company policies that require the wheel weights to be recycled. An estimate derived by talking with industry representatives suggests that approximately 14,000 t, or 75 percent, of the lead in wheel weights recovered by retailers are recycled. Based on the number and type of vehicles retired, about 3,000 t of lead from wheel weights was recovered by automotive scrap dealers in 2003. This estimate does not include commercial trucks, which probably accounted for less than 500 t.

The wheel weights collected by retailers and scrap dealers are smelted with obsolete battery components of similar composition for eventual use in new automobile batteries, new wheel weights, and other products. In 2003, secondary smelting facilities produced approximately 1.15 Mt of lead, of which approximately 92 percent (Smith, 2005) was from vehicle batteries and less than 2 percent from recycled lead wheel weights.

Little is documented concerning the amount of material collected and its fate in this segment of the material flow of lead wheel weights.

Unaccounted Lead Wheel Weights and Possible Fate

About 4,000 t of lead in wheel weights are unaccounted for, but could include weights given or sold by retailers to anglers for making weights and lures; boaters for constructing keels and ballast (Ashmore, 2004); and hunters for making ammunition. Some of the unaccounted tonnage may be disposed of as hazardous waste or placed in landfills, recycled through smelters, stored on-site at businesses, or illegally dumped. The estimated amount of material could also be affected by changes in inventories and to the estimates for lead wheel weights recovered by retailers and scrap dealers and the estimated percentage recycled.

A study focusing on the collection and recycling habits of lead wheel weights collected by tire retailers would better enable an estimate of the actual of the "unaccounted" portion of the materials flow of lead wheel weights.

Conclusion

Much of the emphasis concerning lead wheel weights has been placed on losses during use. However, when viewing lead wheel weights through a model of stocks and flows, it appears that determining the fate of the unaccounted material may also need to be investigated more thoroughly, with a particular emphasis on the disposition of lead wheel weights collected by dealerships, fleet managers, repair shops, and tire retailers.

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