California Environmental Protection Agency
DEPARTMENT OF TOXIC SUBSTANCES CONTROL

WHEEL WEIGHT ALTERNATIVES ASSESSMENT

NOVEMBER 2011

Department of Toxic Substances Control

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

The mission of DTSC is to protect California's people and environment from harmful effects of toxic substances through the restoration of contaminated resources, enforcement, regulation and pollution prevention.

Trina Gonzalez
Deputy Director
Office of Pollution Prevention
and Green Technology

Bob Boughton
Sr. Hazardous Substances Engineer

WHEEL WEIGHT ALTERNATIVES ASSESSMENT

INTRODUCTION

The products we use every day contribute to our comfort and well-being, but may impact resource availability and human and environmental health. Policy makers and businesses are using Life Cycle Thinking (LCT) to evaluate the impacts of products throughout an entire life cycle (including acquiring raw materials, manufacturing processes, transportation, product use, and end of life). To account for impacts across the life cycle phases, a Life Cycle Assessment (LCA) can be used to compile, quantify, and evaluate impacts from resource use (fossil fuels, water), and emissions to air, soil and water.

By evaluating the life cycle impacts of a product and proposed alternative designs (alternatives assessment), manufacturers can make informed decisions to improve their products and processes in a way that avoids shifting burdens or impacts at a given life cycle stage, period of time, or geographic region to another. Using LCA also helps identify regrettable substitutions or unintended consequences. It is also a tool for applying Green Chemistry principles in product design. Overall, the life-cycle approach for assessing products and their alternatives is useful to improve environmental performance, company responsibility, and economic benefits.

Wheel weights are applied to compensate for uneven distribution of weight in vehicle tires and wheels. Approximately 130 million pounds of lead wheel weights were estimated to be on U.S. vehicles in 2003 (USGS Open-File Report 2006–1111) and projecting to California, the 30 million registered vehicles (circa 2003) may have accounted for 16 million lbs of lead wheel weights.

An estimated 3% (Root, 2000. Environmental Health Perspectives 108(10): 937–940) to 10% (USGS Open-File Report 2006–1111) of wheel weights fall off vehicles each year. When lost on roadways, lead can contaminate sources of drinking water, and cause human developmental harm. This has lead to a worldwide effort to eliminate the use of lead based wheel weights In 2009 the California State Legislature enacted a law to reduce lead content in wheel weights to less than 0.1 percent by weight. As a result of phasing out lead wheel weights, alternatives have been developed to meet the main performance criteria: made of a dense material, corrosion resistant, function in a range of operating temperatures, recyclable, and cost-effective. Weights made of steel and zinc alloy meet these criteria, and currently dominate the US market (Personal communications with major wheel weight manufacturers and distributer, 2010).

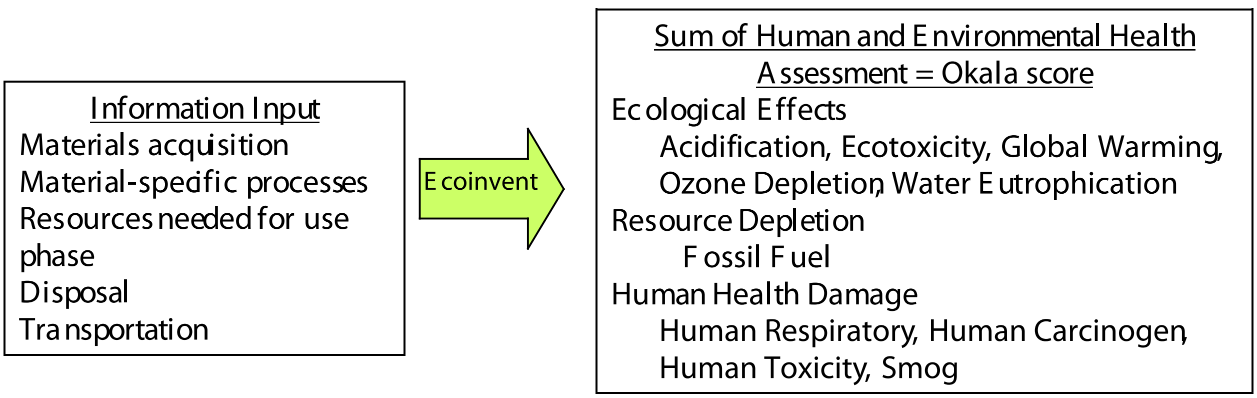
The California Department of Toxic Substances Control (DTSC) decided to employ life cycle assessment tools to evaluate the impacts of alternatives to lead wheel weights currently being used in California. The comparative assessment described in this report evaluates certain impacts associated with lead, steel, and zinc alloy wheel weights to identify regrettable substitutions or burden shifting as a result of the lead wheel weight ban. Metal production inventories were used to compare the impacts of the different wheel weight formulations and to understand the processes contributing to adverse impacts. Impacts from weight losses during use were also evaluated to compare the environmental and human health trade-off.

METHODOLOGY

Assessment using a streamlined quantitative tool

DTSC staff used Sustainable Minds (SM), a simplified product designers' tool that follows standard LCA guidelines (ISO 14040) while streamlining the LCA by generalizing the input selections. SM summarizes the human and environmental health impacts through a weighted impact score, called "Okala", based on data inventories from *ecoinvent* (Figure 1). The results are presented in a scorecard approach illustrating the contribution from the life cycle phases, and the given impact categories. This tool is intended to show the relative improvement of certain life cycle selections and changes for a product design, rather than actual damage or impacts.

Figure 1 Schematic Process of Input and Output of the SM Tool



Project Scope

Staff spoke with manufacturers to identify the most representative wheel weights on the market in California. These include wheel weights made of recycled steel or zinc alloy which connect to the wheel rim using a clip (adhesive applied weights were a minor fraction of the market). Clips are made of steel, regardless of the material content of the weight, and hence were excluded from the analysis. Lead wheel weights were included in the analysis as a baseline material to examine any burden shifting that could result from changing the composition to zinc or steel.

Steel based weights also have a polymer or zinc coating to protect against corrosion. The amount of coating is very small compared to the steel mass and was ignored. Staff also assumed that transportation impacts would be comparable for the types of wheel weight materials, as they are generally the same size, and are manufactured in, and transported from, the same U.S. region. Staff selected a one ounce weight as the reference unit for this analysis.

Input Selections

The boundaries and assumptions identified in the "Project Scope" along with limitations of the SM tool are summarized in Table 1. The database for SM does not have data inventory for producing secondary (recycled) zinc or for weight manufacturing processes. Therefore, direct comparisons are made between producing the metals from primary sources. The comparisons help define the relative impacts of material acquisition. Lastly, SM inventories are constructed such that metals are assumed to be 100%

recycled at end of life, which is a common practice at tire shops. However, it is known that wheel weights are lost during use, then abraded on the roadways, creating potential for impact to human and environmental health. To address this gap, staff examined the impacts of weights lost to the environment separately (see Use phase losses).

Table 1. Input Selections for Wheel Weight life cycle in Sustainable Minds tool

Feedstock Materials		Weight Manufacture	Use-phase resources (power, water, fuel)	End of Life disposition	Transport
Primary Sources	Lead	Excluded	No resources used to install weights or during use	Recycled	Comparable so excluded
	Steel				
	Zinc Alloy				
Secondary Sources	Lead				
	Steel				
	Not Available				

ASSESSMENT USING PROCESS ORIENTED LCA TOOL

GaBi was assessed for ease of use and utility, and to examine the variability between the different inventory databases and assumptions for each tool (i.e., Ecoinvent and GaBi). Users identify the specific process steps and inventories to represent the product life cycle, and choose the impact characterization method (i.e., Traci, US normalization values). GaBi presents the impact potentials in tabular form and optional graphic presentations. Because no secondary metal inventories were available in GaBi, only the results for primary metals were compared with those of SM.

Comparing impact scores

The SM tool produces a normalized (US National Institute of Standards Technology sponsored BEES 4.0 Table 2.14) and weighted (Bare et al., 2006. Environmental Science and Technology, 40 (16): 5108-5115) impact score for a product. The same normalization values were used in GaBi to produce comparable outputs. Hence, the results from each tool reflect only the differences in the data inventories and underlying assumptions. Because the actual scores presented are not so meaningful in terms of context and scale (i.e., 1 oz weight), ratios of the impact values were evaluated.

Use phase losses

It is well known that human health concerns, from losses to the environment during the use phase, drove the decision for the lead weight ban. However, the SM tool did not have the capability of accounting for impacts from wheel weights lost to the environment. Therefore, staff utilized the US EPA TRACI impact factors to gain an understanding of the relative toxicity impacts of lead, steel, and zinc wheel weights when lost on the road. Manufacturers anecdotally stated that the in-use losses are comparable regardless of the weight composition (lead, steel, or zinc). Based on the range of in-use loss estimates (see Introduction), staff assumed 5% wheel weights are lost on the road, and an estimated net 20% degradation occurs. Therefore, the resulting net 1 wt% of the metal is assumed to be dispersed to the environment with subsequent impacts. Therefore, the resulting net 1 wt% of the wheel weight is assumed to be dispersed to the environment with subsequent impacts. Hence, TRACI factors to water and soil (shown in Table 5) were used to quantify potential impacts for 1% of one ounce of metal loss to the environment.

The estimated impact from losses to the environment was also compared to the impacts from primary material acquisition derived from GaBi.

COMPARING AND INTERPRETING RESULTS

Sustainable Minds — the streamlined LCA tool

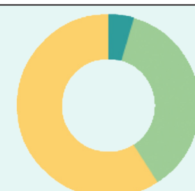
A comparative assessment was performed to identify the relative impacts of acquiring all three metals (lead, steel, and zinc) from primary sources. Primary zinc alloy has the highest Okala score (4.1 mPts per ounce), ten times that of steel (Table 2). The toxicity categories were the main contributors to the scores for each metal type.

Table 2. Impacts from acquiring one ounce of primary metals, assuming 100% recycling at end-of-life using Sustainable Minds

Concept	Primary Lead	Primary Steel	Primary Zinc
Okala mPts	2.6	0.40	4.1
Distribution of Impact Categories			
% Due to Ecological damage			
Acidification	≤ 1	≤ 1	≤ 1
Ecotoxicity	25	**58**	36
Global warming	≤ 1	≤ 1	≤ 1
Ozone depletion	0	0	0
Water eutrophication	0	≤ 1	0
% Due to Resource Depletion			
Fossil fuels	0	≤ 1	0
% Due to Human Health Damage			
Respiratory	≤ 1	≤ 1	≤ 1
Carcinogenicity	31	27	**38**
Toxicity	**44**	15	26
Smog	0	≤ 1	0

The impacts of acquiring metals (lead and steel) from secondary sources, was also performed as it reflects wheel weights available in the market. However, an inventory for secondary zinc was not available. Secondary steel has over twice the Okala score than secondary lead with most of its adverse impacts from depleting fossil fuels and generating smog (Table 3). This is reasonable considering the higher melting point of iron (the dominant metal in recycled steel) versus lead, resulting in higher fuel consumption for steel recycling. Although SM did not contain an inventory for secondary zinc, it is reasonable that the impacts should be between that of secondary lead and secondary steel since the process for secondary zinc (remelting) is similar to that of lead but the melting point of zinc is higher than lead but not as high as that for iron.

Table 3. Results from Sustainable Minds evaluation of impacts from acquiring I oz of secondary metals

Concept	Secondary Lead	Secondary Steel
Okala mPts	0.083	0.22
Distribution of Impact categories		
% due to Ecological damage		
Acidification	≤ 1	≤ 1
Ecotoxicity	**57**	≤ 1
Global warming	≤ 1	0
Ozone depletion	0	4
Water eutrophication	≤ 1	≤ 1
% due to resource depletion		
Fossil fuels	≤ 1	35
% due to Human Health Damage		
Respiratory	≤ 1	≤ 1
Carcinogenicity	26	0
Toxicity	16	≤ 1
Smog	≤ 1	**60**

Comparison of Sustainable Minds and GaBi outputs for acquiring primary metals

The comparison table of normalized impact potentials (using TRACI characterization factors and impact categories) from SM and GaBi (Table 4) shows that SM primary metal impact potentials were usually higher than those from GaBi. The values were most comparable for lead, and are moderately comparable for zinc. However, several divergent values for steel were found, which is likely due to different inventory assumptions for foundry energy inputs and recycled content.

Table 4. Comparison of normalized impact potentials from Sustainable Minds (SM) and GaBi for primary metals production

Normalized value									
TRACI Impact Categories	Lead			Steel			Zinc		
	SM	GaBi	Ratio	SM	GaBi	Ratio	SM	GaBi	Ratio
Acidification	9.6E-06	7.9E-06	121%	1.6E-06	9.7E-07	160%	8.8E-06	3.3E-06	267%
Ecotoxicity	7.8E-03	4.0E-03	194%	2.8E-03	1.0E-04	2780%	1.7E-02	7.0E-03	250%
Global Warming	2.5E-06	2.1E-06	121%	2.1E-06	1.8E-06	114%	4.0E-06	3.7E-06	108%
Human Cancer	8.2E-03	2.2E-02	38%	1.1E-03	1.5E-04	742%	1.6E-02	2.5E-02	64%
Human Respiratory	4.4E-06	3.9E-06	112%	2.1E-06	8.0E-07	267%	4.0E-06	2.0E-06	197%
Human Toxicity	1.9E-02	2.7E-02	69%	9.9E-04	2.6E-04	373%	1.8E-02	3.0E-02	58%
Eutrophication	1.6E-06	8.5E-07	185%	3.2E-06	8.3E-07	390%	2.3E-06	1.6E-06	147%

Impacts from losses to the environment during use phase

Lead and zinc are listed as Priority Toxic Pollutants under the Clean Water Act, while iron is not. Therefore lead and zinc metals were included in this comparison using TRACI impact factors, which illustrates that lead and zinc releases to the environment have high impacts to human health and ecotoxicity, respectively (Table 5). The most significant impact from lead is human toxicity via freshwater contamination. While zinc leads to ecotoxicity via soil contamination, examining the ratio of the TRACI impact factors for lead and zinc (Table 5) illustrates that lead toxicity to humans in freshwater is five orders of magnitude worse than zinc. In soil, zinc toxicity is four orders of magnitude worse than lead. To evaluate which metal is preferred based only on impacts from wheel weights losses to the environment, one would have to make a tradeoff decision—lead is a better choice for limiting ecotoxicity, while zinc is a better choice for limiting human toxicity. However, there is no trade-off decision needed if steel is used. While iron does not have evidence of harmful impact, additives such as nickel and chromium, contained in recycled steel used to make weights, may have a relatively small impact on human and/or environmental health.

Table 5. Comparison of TRACI impact factors for lead and zinc emissions to media

	Human Health (non cancer)			Ecotoxicity		
Media	Lead	Zinc	Ratio Pb/Zn	Lead	Zinc	Ratio Zn/Pb
Soil	1,730,000	11,100	150	0.18	1,740	9,650
Freshwater	11,000,000	18	600,000	2.4	2,050	850
Air	2,170,000	10,250	210	1.44	5,880	4,100

To better assess the impacts of each metal type from the life cycle perspective, the scale of the impacts of metal acquisition needs to be compared to that of losses during use. Table 6 compares the potential human and ecotoxicity impacts (from the GaBi outputs shown in Table 4) for primary metal acquisition (highest impact case) to an estimated 1% net loss to the environment. The ratio of impacts for material loss versus materials acquisition indicates that the loss of lead or zinc to roadways, impacts human health and ecotoxicity (respectively) two orders of magnitude greater than the impacts from metal acquisition (Table 6). Because steel has miniscule toxicity impacts from roadway losses, the ratio comparison for steel weights becomes comparatively very small. Even if the weight manufacturing process (assumed to be equivalent to the secondary metals acquisition) were added to the metal acquisition impacts, the impacts of weights released to the environment would still be far greater.

Table 6. Comparison of normalized impact scores for lead, steel, and zinc primary material acquisition and 1% net loss during use

	Lead		Steel		Zinc	
	Ecotoxicity	Human Toxicity	Ecotoxicity	Human Toxicity	Ecotoxicity	Human Toxicity
Primary metal production 1 oz	4.0 E-3	2.7E-2	1.0 E-4	9.8 E-5	7.0 E-3	3.0 E-2
1 wt% net Loss	4.6E-4	10.7	nil	nil	1.3	1.1 E-03
In-use loss/ production ratio	0.12	**400**	nil	nil	**190**	0.036

CONCLUSIONS

Based on the assumptions and considerations outlined above, lead or zinc wheel weights lost on the roadway have much higher potential impacts to human health or the environment compared to steel. The substitution of zinc for lead weights poses a burden shift as the losses during use are more harmful to the environment than lead. Considering the assumptions outlined above, the impacts, from lead or zinc based wheel weight losses to roadways, greatly exceed their manufacturing impacts. Therefore, steel appears to be the preferred alternative for clip-on weights due to its comparatively low toxicity and reasonable manufacturing impacts. The loss rate for adhesive weights (which represent a minor fraction of the current market) is not known but is likely similar across each weight metal type. Nonetheless, the loss rate for zinc adhesive weights would need to be two orders in magnitude lower than that of steel weights for the loss (during use) impacts to become comparable to those of primary metal acquisition and weight manufacturing for steel weights. Lower environmental and human health impacts coupled with the propensity for steel wheel weights to be made from recycled material appears to position steel wheel weights to be the best overall alternative.