Office of Science

Research Project Summary

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Investigation of release, fate and transport of lead from motor vehicle wheel weights

Authors

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Abstract

Lead is a well-known pollutant with documented toxicity. Lead-containing weights used to balance motor vehicle wheels are regularly lost from vehicles and enter the environment where they are ground into small particles by traffic, thus releasing small particles of lead to the environment and potentially contributing significantly to human exposures. The purpose of this study was to measure the quantity and to assess the form and fate of lead that enters the environment from wheel weights, and to estimate the exposure potential that this lead might represent as compared with other measured and estimated inputs of lead to the environment. This study found that approximately 12 tons per year of lead in the form of wheel weights are deposited on New Jersey roadways, but that only approximately 40 kg of this enters the environment in the form of small particles that are likely to result from the abrasion and grinding action of traffic. This study indicates that, relative to other sources, the amount of lead dispersed in the form of small particles to the environment from wheel weights is small. Further, the quantity of lead released via wheel weights appears likely to decline because of state-level legislation, voluntary phase-outs by manufacturers, and new trends in wheel technology.

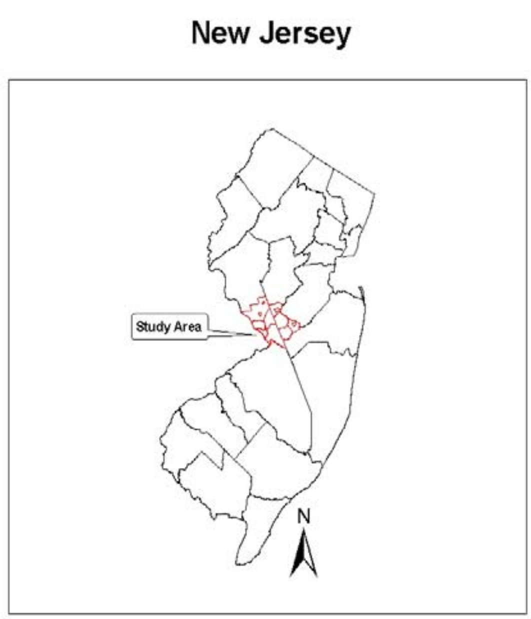
Introduction

Lead is a naturally occurring metal found in the Earth's crust. Human lead exposure is common and results from the many uses of this metal and can impair cognitive function in children and adults.[1] The largest industrial use is for the production of lead batteries, mostly used in the automotive industry; it is also a major component in ammunition, fishing sinkers and automobile wheel weights. The greatest potential for human exposure to lead is believed to arise from its previous use as an additive in gasoline and its use as a pigment in both interior and exterior paint. Despite the banning of lead use in gasoline and paint, human exposure continues because, unlike organic chemicals released to the environment, lead does not degrade to other substances.[2]

A current use of lead is in the manufacture of weights to balance automobile wheels. Wheel weights are attached by steel clips to both the inner and outer wheel rims to ensure that a newly balanced wheel runs smoothly. Out of balance tires tend to vibrate, resulting in excessive wear on tires and vehicle suspension and a compromised vehicle handling at high speeds. Lead wheel weights that fall from vehicles do not enter the recycling stream and may be another potential contributor of lead to the environment.

A recent study, performed by Robert Root, investigated quantities of lead wheel weights falling from motor vehicles onto roads, and estimated the rate at which lead was deposited on and disappeared from roads.[3] It reported an average of 21 g of lead was found on the streets in Albuquerque, NM, and that a steady state quantity, which ranged from 0.35 to 1.1kg/km, was routinely found on roads. The study also found that approximately 9.1 kg/km/year accumulated on roads, which when extrapolated to all urban roads in the US, results in approximately 1.5 million kg year (1500 tons) per year.

Fig. 1 Study area



Methods

In this study a number of roads in Mercer County, New Jersey were surveyed for visible wheel weights (Fig. 1); all weights were collected, measured and weighed. Sampling took place on 23 separate occasions over a period from February of 2006 through January of 2009.

Roads were selected based on land use type and safety issues. All sampling took place on the shoulder, and each segment was sampled in both directions. No major highways or interstates were sampled; however, one site, the Route 1 Bypass, was used to approximate wheel weight amounts on high traffic limited access segments.

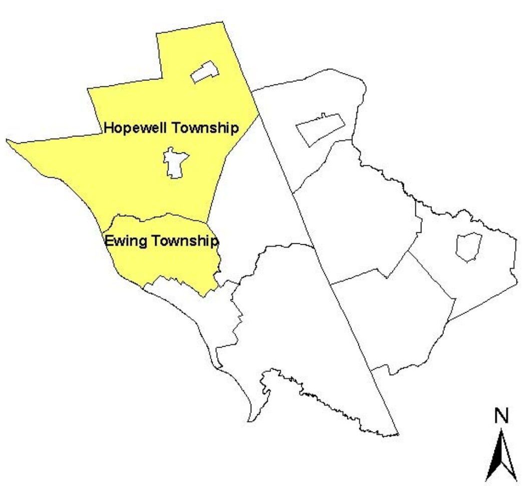
On seven occasions, six groups of three pre-painted and weighed weights were dropped near the center of each side at six locations at the site where the most weights were consistently found. These weights were then collected, and weight loss was recorded.

Roads were characterized utilizing a multi-step approach. Using the NJDEP's computerized geographical information system (GIS), the roads in each of the municipalities in Mercer County were sorted using the TeleAtlas Roads coverage. The roads were separated into two categories: roads with a speed limit of 25 miles per hour (mph) or less, and roads with a speed limit of 35 mph or greater. There were no roads with speed limits between 25 mph and 35 mph. Based on sampling done on various types of roads with speed limits less than 25 mph where no wheel weights were found, it was assumed that since the loss of wheel weights was negligible it was appropriate to lump these roads together as residential roads regardless of whether they were in an urban or rural area. All roads with speed limits greater than 35 mph were mapped and scheduled for ground-truthing. No information on condition of road surfaces was presented in the Root study. This study assumes that the surface condition of roads in New Jersey is not significantly different from the condition of roads in New Mexico.

However, due to the large volume of remaining roads and time constraints, ground-truthing focused on roads within those municipalities that most closely mirrored the land use percentages of the entire state. Based on the state-wide land use percentages, Ewing Township and Hopewell Township were selected as the municipalities with land use percentages most closely resembling those of the entire state (Fig. 2). The roads with speed limits greater than 35 mph in these two municipalities were then

Mercer County

Fig. 2 Municipalities where ground-truthing was performed



driven and characterized as one of four categories: commercial, mixed-use, connector and residential.

Commercial roads were those which were dominated by commercial development, specifically those predominantly populated with strip malls, fast food restaurants, gas stations/ auto repair shops and big box stores. These roads tended to have four lanes with multiple curb cuts and frequent traffic lights with speed limits between 35 and 45 mph, but however, due to high traffic and frequent turning into and out of businesses, traffic generally flowed more slowly with frequent braking.

Mixed-use roads were those with both commercial and residential development but with at least half of its length being commercial. This category tended to have residential development interspersed with strip malls, fast food restaurants, gas stations/auto repair shops, big box stores and office complexes. These roads generally had between two and four lanes with multiple curb cuts and frequent traffic lights with speed limits between 35 and 45 mph. Due to less commercial development, traffic tended to flow at or above posted speed limits with less frequent braking than that of commercial roads.

The connector road category had widely varying types of roads, however all roads within this category, regardless of posted speed limit, had traffic that flowed at or above speed limit, with infrequent braking and few to no traffic lights. This category included high-speed limited access roads, such as interstates and heavily traveled highways; rural connector roads with little to no development other than the occasional house or farm stand; and residential connector roads with close to 100% residential development connecting one neighborhood to another. Based on sampling of each of these types of roads, it was determined that the rate of wheel weight loss was similar and had more to do with the presence or absence of curb cuts and the frequency of braking rather than specific speeds or land use types.

The final category, residential, included neighborhood roads, both suburban and urban with speed limits of 25 mph or slower. Speeds on these roads tended to be slow and braking infrequent and traffic was generally light. Several streets of this type were surveyed on several occasions, and no weights were found. It is assumed that the quantity of dropped wheel weights on this type of road was zero.

Once the roads in these two municipalities were categorized, total mileage of each type of road was calculated for each municipality. The year 2000 population for each municipality was taken from the NJDEP Municipalities GIS coverage and compared to the total state population for that year.

Results

Weights found were typically within a meter of the curb, and mostly out of the normal path of motor vehicles; however, some were found farther out in the street, up on the pavement, or up on the land surface beyond the shoulders of roads. The total number of weights found was 257. The arithmetic mean weight of all weights found was 25.4 ± 1.7 g. The ± range represents the 95% confidence interval, determined using the student's T-test.

As in the Root study, there did appear to be a more or less constant quantity of weights found on road segments. This varied greatly by road type. The mean steady state number of weights found per mile is shown in Table 1. Based on a mean

Table 1 Mean steady state number of weights found/mile by road type with 95% confidence interval

Road Type	Number of weights/mile
Commercial	30.8 ± 9.8
Mixed-use	5.0 ± 3.8
Connector	1.4 ± 1.2

Table 2 Mean steady state weight of collected wheel weights by road typ

Road Type	Mean weight/mile
Commercial	0.49 kg/km
Mixed-use	0.08 kg/km
Connector	0.02 kg/km

weight of 25.4 g, this translated to a mean steady state weight found on the commercial, mixed use, and connector road types of 0.49 kg/km, 0.08 kg/km, and 0.02 kg/km, respectively (Table 2). This report's mean weight found on the commercial road segment is similar to the 0.50 kg/km geometric mean reported by the Root study, but the range of 0.02 to 0.49 kg/km for the different road types represents lower values than the range of 0.35 to 1.1 kg/km reported in that study.

The amount of weights deposited per week was estimated for a heavily-traveled commercial road segment based on seven separate surveys that were conducted at intervals that varied from seven to 48 days. This quantity was estimated at 9.2 ± 5.2 weights per mile per week (5.7 ± 3.2 weights per km per week), which would translate to approximately 300 weights per km per week, or about 7.5 kg/km/year. This is in close agreement with the deposition rate of 9.1 kg/km/year found in the Root study.

The amount of weights deposited per week was projected to the entire state of New Jersey by totaling up the lengths of the three road types in the two municipalities noted above, multiplying these total lengths by the quantity of weights found per length per road type, and then multiplying the resulting totals by the ratio of the entire New Jersey population to the total population of these two municipalities. This approach led to an estimated 12 metric tons per year deposited in the entire state, although there is considerable uncertainty and the quantity could be somewhat higher. Since New Jersey's population is slightly less than 3% of the U.S. population, this suggests that the national rate is approximately 400 tons per year. Note that this total is approximately one-third of that estimated by the Root study. However, had this current study assumed that the connector and mixed use road types had two-thirds the deposition rate of the commercial road types instead of the actual measurement-based deposition rates as used, which would apparently resemble the method used in the Root study; the projected statewide total would have been considerably higher.

The rate at which weights were estimated to be deposited was compared with the steady state quantities found. The deposition rate corresponds to approximately 14 steady state quantities deposited per year, suggesting that approximately 5% of the mass of weights is lost from roads each day. This loss rate is somewhat higher than the 2.72% per day loss rate reported by Root.

This loss rate was not consistent with the rate at which the painted weights that were seeded and then recovered were found to have loss mass, however. This mass loss rate, based on 52 weights that were recovered and compared with their initial weight when dropped in the road, was 13.8 ± 5.0 % per year due to abrasion and grinding by traffic, which is equivalent to a daily loss rate of 0.04% ± 0.01 % (Table 3). It is possible that this estimated mass loss rate is underestimated; some of

Table 3 Summary statistics: weight loss observed from measurements of painted, seeded weights

	Period (days)	Initial weight (g)	Retrieved weight (g)	Weight loss (g)	%loss/day	%lost/year
Mean	19.9	35.56	33.36	0.19	0.04%	13.78%
95% C.I.					0.01%	4.98%

the weights that were not recovered could theoretically have been ground down to particles too small to notice by traffic. However, because the average mass lost between seeding and recovery of the weights that were recovered was 0.2 g, and because no weight recovered had lost more than 1 gram during the period it was exposed to traffic, the possibility that a separate group of weights had disappeared entirely is remote.

It was assumed that grinding and abrasion of weights by traffic produces small particles that can be dispersed relatively easily. It was also assumed that this grinding and abrasion effect should be proportional to the amount and speed of traffic on a road, which in turn should be proportional to the amount of weights found on a road, and would thus be considerably less for the mixed use and connector road types that in this study were found to have a lower steady state quantity of weights. With the assumption that the wear rate was proportional in this manner, and that the study area was representative of the entire state, it was estimated that approximately 40 kg of such small particles are produced statewide per year. If, however, a 13.8% per year wear rate were assumed to exist for all roads, the estimated quantity of small particles produced would be approximately 150 kg/year.

Discussion

This study, like the Root study, found that weights disappear from roads at a relatively rapid overall rate. This overall loss rate is estimated in this study to be approximately 5 % per day, which is in approximate agreement with the 2.72 % per day estimated by Root. However, this study also measured the rate at which the weights are worn away by the abrasion and grinding effects of traffic. This rate is approximately 0.04% per day, indicating that there are other ways that weights are lost from road surfaces, and that these other ways represent a much larger component of the loss process.

Based on the frequent finding of weights on pavements and beyond road shoulders, it is likely that weights are moved considerably by traffic and are likely to be eventually flung out of the path of vehicles and into culverts or other drainage structures. In addition, many of the roads surveyed were routinely cleaned by motorized street sweepers, which were observed to remove a portion of the weights. It is thought that this could also be a major route of loss of weights, and it is likely that these weights, once removed from the roadway, do not degrade rapidly in the environment.

The estimated input of relatively small particles of lead from wheel weights is likely represented by that portion of the loss rate that is due to abrasion and grinding of lead wheel weights by traffic. This quantity should be compared with inputs of finely dispersed lead from other sources and the reservoir of finely dispersed lead still present from its previous use in paint and gasoline.

A study of inputs of numerous pollutants, including lead, through both wet and dry deposition was carried out in New Jersey during the period 1998 to 2001.[4] This study found a yearly wet deposition of approximately 40 metric tons, and a yearly dry deposition of approximately 20 tons. With the assumption that similar values exist in 2009, a total in the range of 60 tons of lead enters the New Jersey environment each year from atmospheric deposition.

Further, unleaded gasoline and diesel fuel have been found to contain lead at levels ranging from tens to hundreds of parts per billion, and leaded gasoline continues to be sold for off-road uses, especially marine and aviation engines.[5] Three-fourths of the US fleet, between 167,000 and 220,000 aircraft, are piston-powered certified to fly on leaded 100LL fuel, which contains up to 2.2 grams of lead per gallon.[6] In New Jersey in 2004, c 3,696,000 gallons were used; this corresponds to approximately 8 tons of finely dispersed lead released into the air.

In addition, historical uses of lead, particularly in gasoline and paint, still persist in the environment. Since the ban of lead in gasoline, lead emissions from traffic have decreased significantly, however lead in road dust can still be a problem. Although most studies have seen a decrease in lead content in road dust,[7,8,9] it has also been found that rain does not necessarily wash off fine particles that are attached to asphalt, so lead emitted from leaded gasoline can still pose a public health risk.[10] Residential lead paint also continues to be a problem. According to the US Geological Survey's American Housing Survey, from 1914 to 1978, 1,004,000 tons of lead was used in residential paint. Even after demolition and renovation, 841,000 tons of lead paint still remains on housing.[11]

Summary

This study has confirmed the finding of an earlier study that leaded wheel weights fall off motor vehicles, are deposited on roads, and routinely disappear from these roads. However, unlike this earlier study, this study has found that the rate at which the weights are worn down by traffic is too small to contribute significantly to the observed loss rate of weights from roads, and that therefore other mechanisms, including street sweeping, and being flung or knocked from roads to adjacent land areas or into culverts and other drainage channels are likely the main loss mechanisms of deposited weights.

This study estimates that approximately 12 tons per year of lead in the form of wheel weights are deposited on New Jersey roadways, but that only approximately 40 kg of this enters the environment in the form of small particles that are likely to result from the abrasion and grinding action of traffic. This 40 kg/year quantity of small particles dispersed from wheel weights is less than 0.7% of the measured input through atmospheric deposition of finely dispersed lead to the New Jersey environment of approximately 60 tons per year, some of which may result from the combustion of leaded aviation fuel, which appears to contribute in the range of 8 tons per year to the atmosphere in New Jersey. The 40 kg/year quantity should also be compared with the likely high fluxes of lead into the environment that still continue from leaded paint, and with the residue of finely dispersed lead from historical uses of leaded gas in motor vehicles that remains in the environment. This study indicates that, relative to these sources, the amount of lead dispersed in the form of small particles to the environment from wheel weights is small. Further, the quantity of lead released via wheel weights appears likely to decline because of state-level legislation, voluntary phase-outs by manufacturers, and new trends in wheel technology.

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