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**To** Rich Mason, U.S. Environmental Protection Agency

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**Subject** Documentation for Estimation of 2014 Nonpoint Mercury Emissions

## Introduction

This memorandum includes the documentation for the estimation of nonpoint source mercury emissions in 2014. Table 1 summarizes the national emissions (lbs.) estimated for each source category. The remainder of the memo discusses the methodology for estimating emissions for each source category, including the estimation of activity data, emissions factors, approach for allocating emissions to the county level, sample calculations, and references.

**Table 1.** National nonpoint emissions of mercury (lbs.) in 2014.

Source Category	SCC	2014 Emissions (lbs.)
Switches and Relays	2650000002	3,273.19
Human Cremation	2810060100	3,302.92
Landfills	2620030001	757.27
Fluorescent Lamp Breakage	2861000000	1779.06
Dental Amalgam	2850001000	921.99
General Laboratory Activities <sup>a</sup>	2851001000	600.0
Thermostats	2650000000	230.86
Animal Cremation	2810060200	81.10
Thermometers	2650000000	10.73
Fluorescent Lamp Recycling	2861000010	0.64
Batteries	TBD	0.0
<b>TOTAL</b>		<b>10,957.76</b>

<sup>a</sup> The 2014 estimate of mercury emissions from general laboratory activities is pulled forward from the 2008 NEI.

## Switches and Relays

Switches and relays make up the largest potential source of mercury from products that intentionally contain mercury. Mercury is an excellent electrical conductor and is liquid at room temperature, making it useful in a variety of products, including switches used to indicate motion or tilt, as the mercury will flow when the switch is in a certain position, completing the circuit.

While mercury switches in cars were phased out as of the 2002 model year, there are still millions of cars on the road that contain them, which are potential emissions sources when the cars are recycled at the end of their useful lives, which involves crushing and shredding cars. The shredded material is then sent to an arc furnace to recycle the steel. To avoid double counting point source emissions from arc furnaces, this source category only includes an estimate of nonpoint emissions from crushing/shredding operations.

### *Activity Data*

The End of Life Vehicle Solutions Corporation (ELVS) provides information on the estimated number of switches available for recovery in each state and the amount of switches actually recovered in 2014.

There were 2.6 million mercury-containing automobile switches available nationwide in 2014 and 513,877 switches collected for recycling, for a collection rate of 19.67%.

Therefore, there were approximately 2.1 million unrecycled automotive switches in 2014.

### *Allocation Approach*

The number of unrecovered switches is apportioned to each county based on the number of car recycling facilities (NAICS 423930) from the 2014 US Census Bureau County Business Patterns.

### *Emission Factor*

The response to comments for the 2007 EPA Significant New Use Rule on Mercury Switches (72 Fed. Reg. 56903), suggests that the weighted average amount of mercury in switches is 1.2 grams (0.0026 lbs.). A report by Griffith et al. (2001) shows that 60% of mercury in switches is released at the shredding operation, while 40% is sent to arc furnaces for smelting. Therefore, the emission factor for switches is 0.00156 lbs. per switch.

### *Example Calculation*

Alabama had 53,811 unrecovered vehicle switches in 2014. Baldwin County, AL has 4 car recycling facilities, which represents 2% of the facilities in the state. Therefore, that county is apportioned switches as follows:

$$53,811 \text{ switches in AL} \times 2\% = 1,092.6 \text{ switches in Baldwin}$$

County, AL Emissions are estimated as follows:

$$1,092.6 \text{ switches} \times 0.00156 \text{ lbs./switch} = 1.70 \text{ lbs. Hg emissions}$$

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## Human Cremation

The cremation of individuals with mercury fillings and mercury in blood and tissues can result in mercury emissions. Cremation is becoming increasingly popular; in 2010, 40.6% of individuals were cremated in, up from 33% in 2006 (CANA 2011). The National Funeral Directors Association (NFDA) estimated that 46.7% of individuals in the U.S. were cremated in 2014 (NFDA, 2014).

### *Activity Data*

The Centers for Disease Control and Prevention WONDER database contains information on the number of deaths in each county in each year in 13 different age groups through 2014 (CDC 2014, Table 2). Data for some counties were withheld in the WONDER database. These gaps were filled using the state totals (which included the number of deaths that were withheld at the county level). The difference between the state-level data and the sum of the reported county-level deaths was apportioned to the counties not included in the WONDER database based on their population.

NFDA (2014) provides estimates of cremation rates through 2030. It is assumed that the state-level cremation rate applies to all counties in the state.

**Table 2.** Comparison of age groups in the CDC WONDER Database (activity data) and the BAAQMD memorandum (emission factor data).

Age Groups in CDC WONDER Database	Age Groups in BAAQMD Memorandum	Avg. Material in Restored Teeth (g)	% of Fillings Containing Mercury	% of Mercury in Dental Amalgam
< 1 year	0-4 years*	0.000	0.0%	45.0%
1-4 years		0.160	31.6%	45.0%
5-9 years	5-14 years	0.720	31.6%	45.0%
10-14 years		0.720	31.6%	45.0%
15-19 years	15-24 years	1.070	31.6%	45.0%
20-24 years		1.070	50.0%	45.0%
25-34 years	25-34 years	2.230	50.0%	45.0%
35-44 years	35-44 years	3.290	62.5%	45.0%
45-54 years	45-54 years	4.310	62.5%	45.0%
55-64 years	55-64 years	4.320	75.0%	45.0%
65-74 years	65-74 years	3.780	75.0%	45.0%
75-84 years	75-84 years	3.650	75.0%	45.0%
85+ years	85+ years	2.960	75.0%	45.0%

\* It is assumed that children under the age of 1 have no dental mercury.

### ***Allocation Approach***

The CDC WONDER database contains data at the county level. The CANA statistics on the cremation rate are at the state level, but it is assumed that this rate applies to all counties in the state.

### ***Emission Factor***

The Bay Area Air Quality Management District (BAAQMD) issued a memorandum calculating the average amount of dental mercury in each human in 10 different age groups based on data from the CDC's National Health and Nutrition Examination Survey (NHANES) (Lundquist 2012). The age groups from the BAAQMD memorandum match well with the age groups from the CDC WONDER database (Table 2).

The emission factors were determined by using the NHANES data to determine the number of individuals in each age group with 1, 2, 3, or 4 or more restored teeth. This was used along with a published report that estimated the average mass of material in tooth restorations used in 1, 2, 3, or 4 or more teeth to determine a weighted average mass of material in tooth restorations per individual in each age group (Adegbembo et al. 2004).

The analysis then accounts for the fact that not all fillings are made with mercury. According to the American Dental Association (ADA 1998) more than 75% of restorations before the 1970s used dental amalgam, which declined to 50% by 1991. Using these numbers, it is assumed that 50% of the filled teeth for 20-34 age group contain amalgam, 62.5% of filled teeth in the 35-49% age group, and 75% of filled teeth for people over 50. The BAAQMD memorandum was used to estimate that 31.6% of filled teeth in the 1-19 age group contain amalgam. The analysis also assumes that 45% of all amalgam-containing fillings are mercury.

The BAAQMD memorandum states that their assumptions are conservative and could result in an overestimation of mercury emissions given that the analysis assumes that none of the mercury initially placed in the teeth is lost over time, despite the fact that data shows some loss of mercury from dental restorations, though the rate of loss is dependent on many factors, including area, age, and composition of the amalgam.

In addition to the amount of mercury in teeth, Reindl (2012) estimates mercury emissions from blood and tissues (but not dental amalgam) from humans at 0.000132 lbs./cremation, assuming an average weight at cremation of 176 lbs.

### ***Example Calculation***

#### **Estimating mercury in teeth:**

There were 112 deaths in the 75-84 year age group in Autauga County, AL in 2014. The emission factor for that age group is 1.2319 grams of mercury, or 0.0027 lbs., per cremated human. Alabama has a cremation rate of 23.1%. To calculate the mercury emissions from this age group, these numbers are multiplied together:

$$112 \text{ deaths in the 75-84 year age group} \times 23.1\% \text{ cremation rate} \times 0.0027 \text{ lbs. Hg/cremation} \\ = 0.069 \text{ lbs. Hg emissions for the 75-84 year age group in Autauga}$$

County, AL Estimating mercury in blood and tissues:

$$112 \text{ deaths in the 75-84 year age group} \times 23.1\% \text{ cremation rate} \times 0.000132 \text{ lbs. Hg/cremation} \\ = 0.00342 \text{ lbs. Hg emissions for the 75-84 year age group in Autauga}$$

County, AL Total mercury emissions:

$$0.069 + 0.00342 = 0.0733 \text{ lbs. Hg}$$

emissions This is repeated for each age group in Table 2 in each county.

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## **Landfills**

While the amount of mercury in products placed in landfills has tended to decrease in recent years, there is still a significant amount of mercury in place at landfills across the country. There are three main pathways for mercury emissions at landfills: (1) emissions from landfill gas (LFG) systems, including flare and vented systems; (2) emissions from the working face of landfills where new waste is placed; and (3) emissions from the closed, covered portions of landfills (Lindberg et al. 2005). Emissions from LFG systems are considered point sources and are already included in the NEI. Lindberg et al. (2005) found that emissions from the closed, covered portions of landfills are negligible and are similar to background soil emission rates. Therefore, this methodology focuses on emissions from the working face of landfills.

### ***Activity Data***

The US EPA's Landfill Methane Outreach Program (LMOP) maintains a database of the landfills in the United States with information on the total amount of waste in place, as well as the opening and closing years of the landfill and the county where the landfill is located (US EPA 2014a). The average number of tons of waste each landfill receives is estimated by dividing the total waste in place by the number of years the landfill has been operating. Only landfills that were open in 2014 are included in the analysis.

### ***Allocation Approach***

The EPA LMOP database provides data at the county level.

### ***Emission Factor***

Lindberg et al. (2005) measured mercury emissions from the working face of four landfills in Florida and determined emission factors per ton of waste placed in a landfill annually, ranging from 1-6 mg per ton of waste. The average of these emission factors is 2.5 mg/ton of waste, or  $5.51 \times 10^{-6}$  lbs./ton of waste.

### ***Example Calculation***

The New Hanover County Secure Landfill in New Hanover, NC is estimated to receive approximately 117,368 tons of waste annually.

$$117,368 \text{ tons of waste} \times 5.51 \times 10^{-6} \text{ lbs. Hg/ton of waste} = 0.65 \text{ lbs. Hg emissions}$$

## **Fluorescent Lamp Breakage**

Fluorescent lights are a potentially significant source of mercury emissions. Although each lamp contains only a small amount of mercury, which has been decreasing in recent years, the increased demand for fluorescent lamps, particularly compact fluorescents, driven partly by the phase out of many types of incandescent bulbs from the Energy Independence and Security Act of 2007 (PL 110-140 § 321), could lead to increases in mercury emissions.

### ***Activity Data***

Data from a Freedonia Group Industry Study on the U.S. lamp market was used to estimate that 1.4 billion mercury containing lamps, including CFLs and high impact discharge (HID) lamps, were discarded or recycled in 2014. Bulb sales for 2002, 2007, 2012 and projections for 2017 were obtained from Freedonia; sales for all other years were calculated by extrapolating data. Average rated life (hrs) of lamp types were used to calculate lifetimes (yrs), assuming that CFLs are on for 4 hours per day and all other fluorescents and HIDs are on for 8 hours per day (Buildings.com, 2008).

According to a 2010 study by Silveira and Chang, the recycling rate for mercury containing lamps in the U.S. is 23%. Taking into account recycling, this suggests that there were approximately 1.1 billion mercury-containing lamps discarded at landfills in 2014.

### ***Allocation Approach***

The national-level mercury emissions from fluorescent lamp breakage are allocated to each county based on population.

### ***Emission Factor***

Cain et. al (2007) provides the most comprehensive materials flow analysis of mercury intentionally used in products. Their analysis estimates that 10% of all mercury used in fluorescent light bulbs is eventually released to the atmosphere after production and before disposal, with the majority being released during transport to the disposal facility.

The average amount of mercury in a CFL has been studied extensively, with the amount of mercury in each CFL commonly reported as 1.27–4.0 mg (2.63 mg average, Table 3). Linear fluorescent bulbs contain more mercury than CFLs, with a range of 8.3 to 12 mg per bulb (10.15 average, Table 4). Data from the USGS suggests that there is an average of 17 mg of mercury per HID bulb (Goonan 2006).



**Table 3.** Mercury used in CFLs (mg/bulb) as determined by three different studies.

<b>Study</b>	<b>Average Amount of Mercury per CFL (mg)</b>
Li and Jin (2011)	1.27
Katers et al. (2009)	4.00
Singhvi et al. (2011)	2.63
<b>Average</b>	<b>2.63</b>

**Table 4.** Mercury used in linear fluorescent bulbs (mg/bulb) as determined by two different studies.

<b>Study</b>	<b>Average Amount of Mercury per Linear Fluorescent Bulb (mg)</b>
Aucott et al. (2004)	12.0
NEMA (2005)	8.3
<b>Average</b>	<b>10.2</b>

Therefore the emission factor for CFLs would be:

$$2.63 \text{ mg per CFL} \times 10\% = 0.263 \text{ mg of emissions per CFL}$$

The emission factor for linear bulbs would be:

$$10.15 \text{ mg per linear bulb} \times 10\% = 1.015 \text{ mg per linear bulb}$$

The emission factor for HID bulbs would be:

$$17 \text{ mg per HID bulb} \times 10\% = 1.7 \text{ mg per HID bulb}$$

### ***Example Calculation***

Emissions from CFLs:

$$\begin{aligned} & 519 \text{ million discarded CFLs} \times 0.263 \text{ mg per CFL} \\ & = 136.4 \text{ million mg mercury emissions from CFLs} \end{aligned}$$

Emissions from linear bulbs:

$$\begin{aligned} & 463 \text{ million discarded linear bulbs} \times 1.015 \text{ mg per bulb} \\ & = 472.3 \text{ million mg mercury emissions from linear} \end{aligned}$$

bulbs Emissions from HID bulbs:

$$\begin{aligned} & 112 \text{ million discarded HID bulbs} \times 1.7 \text{ mg per bulb} \\ & = 190.3 \text{ million mg mercury emissions from HID} \end{aligned}$$

bulbs Total mercury emission from breakage of mercury-containing bulbs:

$$\begin{aligned} & 136.4 \text{ million mg} + 472.3 \text{ million mg} + 190.3 \text{ million mg} = 799 \text{ million mg} \\ & = 799 \text{ kg} \\ & = 1,758 \text{ lbs. mercury emissions} \end{aligned}$$

Weston County, WY was estimated to have 7,201 people in 2014, or 0.0023% of the national population. The emissions for Weston County are estimated as follows:

$$1,758 \text{ lbs. national Hg emissions} \times 0.0023\% \text{ of national population} = 0.04 \text{ lbs. Hg emissions}$$

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## Dental Amalgam

Dental amalgam is used to fill cavities in teeth, and it is composed of approximately 45% mercury (Lundquist 2012). The use of mercury in dental amalgam is declining, however, due to the increased popularity of composite fillings for teeth (Vandeven 2005). Nevertheless, there is still a small amount of mercury emissions from dental amalgam in restored teeth. There are two potential sources of mercury emissions from dental amalgam: emissions from the preparation of amalgam in dental offices and a small amount of emissions directly from restored teeth.

### *Activity Data*

According to a NEWMOA's IMERC factsheet (2015), the amount of mercury in dental amalgam was estimated to be 15.97 tons (31,940 lbs.) in 2013.

The amount of mercury emissions from restored teeth was estimated using data from the National Institutes of Health's National Institute of Dental and Craniofacial Research (2013), which provides estimates of the average number of filled teeth per person in three different age brackets: 20-34 years, 35- 49 years, and 50-64 years. The number of filled teeth for other age groups was estimated using the CDC National Health and Nutrition Examination Survey (NHANES). Table 5 lists the average number of filled teeth per person by age group.

**Table 5.** Average number of filled teeth per person and percentage of fillings containing mercury by age group.

Age Group	Average Number of Filled Teeth Per Person	Percentage of Fillings Containing Mercury
0-5	0.44	31.6%
5-19	1.23	31.6%
20-34	4.61	50.0%
35-49	7.78	62.5%
50-64	9.20	75.0%
65+	6.47	75.0%

According to the American Dental Association (ADA 1998) more than 75% of restorations before the 1970s used amalgam, which declined to 50% by 1991. Using these numbers, it is assumed that 50% of the filled teeth for 20-34 age group contain amalgam, 62.5% of filled teeth in the 35-49% age group, and 75% of filled teeth for people over 50. The BAAQMD memorandum was used to estimate that 31.6% of filled teeth in the 1-19 age group contain amalgam.

### ***Allocation Approach***

The emissions from dental office preparations were allocated to the county level based on population.

The emissions from filled teeth were allocated to each county by multiplying the county population by the proportion of the national population in each age group (from U.S. Census Bureau data), the average number of filled teeth per person, and the percentage of fillings containing mercury (Table 5). The emissions were then added across age groups.

### ***Emission Factor***

US EPA (1997) estimates that 2% of mercury used in dental offices is emitted to the air.

Richardson et al. (2011) estimate emissions from filled teeth of approximately 0.3 µg/day of mercury emissions per filled tooth, or  $2.4 \times 10^{-7}$  lbs. per year per filled tooth.

### ***Example Calculation***

Emissions from dental office preparations:

$$31,940 \text{ lbs. Hg} \times 2\% = 638.8 \text{ lbs. emissions}$$

Orleans Parish, LA has 384,320 people, representing 0.121% of the national population. The mercury emissions from dental office preparations in Orleans Parish are estimated by the following:

$$638.8 \text{ lbs. national emissions} \times 0.121\% = 0.770 \text{ lbs. Hg mercury emissions from dental offices}$$

Emissions from restored teeth:

Nationally, 14.5% of the population is in the 65+ age group. This age group has an average of 6.47 fillings per person, and 75% of their fillings contain mercury. The emissions from restored teeth in Orleans Parish, LA are estimated by the following:

$$\begin{aligned} & 384,320 \text{ people} \times 14.5\% \text{ in 65+ age bracket} \times 6.47 \text{ fillings per person} \times 75\% \text{ of fillings with mercury} \\ & \times \\ & 2.4 \times 10^{-7} \text{ lbs. per year per filled tooth} \\ & = 0.065 \text{ lbs. mercury in the 65+ age bracket in Orleans} \end{aligned}$$

Parish This is repeated for each age group in Table 5 for each county.

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita

emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## **General Laboratory Activities**

Documentation for previous versions of the NEI have cited personal communications with USGS staff for estimates of the amount of mercury used in general laboratory activities. In discussions with Robert Virta of the USGS (2013), it was determined that because the USGS stopped conducting its survey of the end uses of mercury in the economy in 2002 it would be impossible to state with any confidence an estimate of the amount of mercury used in general laboratory activities in 2014. The estimate from the 2008 NEI was pulled forward for the 2011 NEI. Further literature searches again revealed no data that could be used to estimate mercury emissions for this source category; therefore the estimate from the 2008 NEI was pulled forward for the 2014 NEI.

## **Thermostats**

Mercury has been used in thermostats to switch on or off a heater or air conditioner based on the temperature of a room. Most of the historic production of mercury thermostats came from three corporations: Honeywell, White-Rogers, and General Electric. In 1998 these corporations formed the Thermostat Recycling Corporation (TRC), a voluntary program that attempts to collect and recycle mercury thermostats as they come out of service.

### ***Activity Data***

The 2002 EPA report estimated that 2-3 million thermostats came out of service in 1994 (Leopold 2002). A 2013 report from a consortium of environmental groups assumes that the estimate from the 2002 report remains viable and it estimates that the TRC collects at most 8% of the retired thermostats each year (Natural Resources Defense Council et al. 2013). A literature search revealed no new data that could be used to estimate the number of thermostats coming out of service. Therefore, using this estimate, there are approximately 2.3 million thermostats that are not recycled each year.

### ***Allocation Approach***

The national-level mercury emissions are apportioned to each county based on population.

### ***Emission Factor***

The 2002 EPA report estimates that there are 3 grams of mercury per thermostat (Leopold 2002). Cain et al. (2007) estimate that 1.5% of mercury in “control devices,” including thermostats, is emitted to the air before it is disposed of at a landfill or incinerator. Therefore the amount of mercury emitted is 0.045 grams per thermostat, or  $9.9 \times 10^{-5}$  lbs. per thermostat.

### ***Example Calculation***

2.3 million improperly disposed thermostats  $\times$   $9.9 \times 10^{-5}$  lbs. per thermostat = 228 lbs. mercury emissions

Shelby County, TN has 938,803 people, or 0.29% of the national population. The mercury emissions from thermostats in Shelby County, TN are estimated by the following:

$$228 \text{ lbs. national mercury emissions} \times 0.29\% = 0.672 \text{ lbs. mercury emissions}$$

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita emission factor is multiplied by the county population (from the same year as the inventory’s activity data) which served as the activity data. In these cases, the throughput (activity data) unit

and the emissions denominator unit are “EACH”.



## **Animal Cremation**

Animal tissues contain mercury, similar to humans. A 2012 survey from the Pet Loss Professionals Alliance (PLPA 2013) found that 99% of deceased pets are cremated, with the remaining 1% receiving burial. Therefore, mercury from animal tissues through cremation can be a source of nonpoint mercury emissions.

### ***Activity Data***

The PLPA survey estimates that there were 1,840,965 pet cremations in 2012. In addition, the Humane Society of the United States (2014) estimates that there are 2,700,000 adoptable dogs and cats euthanized in animal shelters each year. It is assumed that all of these shelter animals are cremated. Therefore, there are a total of approximately 4,540,965 animal cremations each year. Note that this estimate does not double count the number of animal cremations, because the PLPA study counts the number of cremations of pets—i.e. animals that are owned by people—whereas the Humane Society estimates are for animals in shelters that were not adopted.

The population of cats and dogs is approximately 52.5% cats and 47.5% dogs (Humane Society 2014). The average weight of a domestic cat is approximately 12.5 lbs. (National Geographic 2014). The average weight of a dog is difficult to determine due to large differences in breeds, but one estimate suggests it is 35 lbs. (Animal Ark 2012). Therefore, the total weight of cremated animals is approximately 53,441 tons.

### ***Allocation Approach***

The national-level mercury emissions from animal cremation are allocated to the county level based on population.

### ***Emission Factor***

Emission factors for mercury emissions from animal cremations are not available from the literature. Reindl (2012) estimates mercury emissions from blood and tissues (but not dental amalgam) from humans at 0.0015 lbs./ton. This emission factor appears to be the most appropriate emission factor for animals, given that it does not include dental amalgam.

### ***Example Calculation***

Total mercury emissions from animal cremations:

$$53,441 \text{ tons cremated animals} \times 0.0015 \text{ lbs./ton} = 80.2 \text{ lbs. mercury emissions}$$

Walla Walla County, Washington has 59,844 people, or 0.019% of the national population. The mercury emissions from animal cremations in Walla Walla are estimated by the following:

$$80.2 \text{ lbs. national mercury emissions} \times 0.019\% = 0.015 \text{ lbs. mercury emissions}$$

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## **Thermometers**

Mercury thermometers have all but been phased out in the United States, with the USEPA and National Institute of Standards and Technology (NIST) working to phase out mercury thermometers in industrial and laboratory settings. NIST issued notice in 2011 that it would no longer calibrate mercury-in-glass thermometers for traceability purposes. EPA issued a rule in 2012 that provides flexibility to use alternatives to mercury thermometers when complying with certain regulations pertaining to petroleum refining, power generation, and PCB waste disposal (US EPA 2014b). Furthermore, thirteen states have laws that limit the manufacture, sale, and/or distribution of mercury-containing fever thermometers (US EPA 2014b).

Nevertheless, given the historical prevalence of mercury thermometers, it is likely that a significant amount of mercury remains in thermometers in homes in the United States.

### ***Activity Data***

Data from a NEWMOA's IMERC factsheet suggests that there were 546 lbs. of mercury used in thermometers in 2013 (NEWMOA, 2015). We assume that this value is held constant each year through 2014.

The US EPA assumes that the average lifespan of a glass thermometer is 5 years, and that 5% of glass thermometers are broken each year (Leopold 2002).<sup>1</sup> Therefore, if 546 lbs. of mercury are used in thermometers each year there would be an estimated 2,470 lbs. of mercury remaining in thermometers in 2041 (accounting for the breakage rate each year).

King et al. (2008) estimate that during the period 2000-2006 there were 350 lbs. of mercury from thermometers collected in recycling programs.

Therefore, there were 2,120 lbs. (1.06 tons) of mercury available for release in 2014.

### ***Allocation Approach***

The national-level mercury emissions from thermometers are allocated to the county level based on population.

### ***Emission Factor***

Cain et al. (2007) estimate that 10% of mercury from thermometers is emitted to the air before disposal in a landfill, and Leopold (2002) estimates that 5% of thermometers are broken each year. Therefore the emission factor is estimated to be 10 lbs. of mercury emissions per ton of mercury in thermometers.

### ***Example Calculation***

1.06 tons of mercury in broken thermometers  $\times$  10 lbs. emissions per ton = 10.6 lbs. of emissions

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<sup>1</sup> The US EPA does not explain what happens to the remaining 75% of unbroken thermometers after the estimated 5- year lifespan, but it does suggest that recycling, such as through Fisher Scientific's thermometer trade-in program, may account for some of the remaining thermometers.

Boise County, ID has 76,824 people, or 0.0021% of the national population. The mercury emissions from broken thermometers for Boise County are estimated by the following:

$$10.6 \text{ lbs. national emissions} \times 0.0021\% = 0.00022 \text{ lbs. emissions}$$

### ***Puerto Rico and US Virgin Islands Emissions Calculations***

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## Fluorescent Lamp Recycling

In addition to emissions of mercury from the breakage of fluorescent light bulbs (SCC 2861000000), there are a small amount of emissions from recycling fluorescent bulbs.

### *Activity Data*

Data from a Freedonia Group Industry Study on the U.S. lamp market was used to estimate that 1.4 billion mercury containing lamps, including CFLs and high impact discharge (HID) lamps, were discarded or recycled in 2014. Bulb sales for 2002, 2007, 2012 and projections for 2017 were obtained from Freedonia; sales for all other years were calculated by extrapolating data. Average rated life (hrs) of lamp types were used to calculate lifetimes (yrs), assuming that CFLs are on for 4 hours per day and all other fluorescents and HIDs are on for 8 hours per day (Buildings.com, 2008).

According to a study 2010 study by Silveira and Chang, the recycling rate for mercury containing lamps in the U.S. is 23%. Taking into account recycling rates, this suggests that there were approximately 327 million mercury-containing lamps recycled in 2014.

### *Allocation Approach*

The national-level mercury emissions from the recycling of mercury-containing lamps are allocated to each county based on population.

### *Emission Factor*

The US EPA (1997) has estimated an emission factor from mercury-containing bulb recycling of 0.00088 mg/lamp ( $1.9 \times 10^{-9}$  lb./lamp).

### *Example Calculation*

Emissions from recycling of mercury-containing bulbs:

$$327 \text{ million bulbs recycled} \times 1.9 \times 10^{-9} \text{ lb./lamp} = 0.6 \text{ lbs. mercury emissions}$$

Cumberland County, ME has a population of 281,797 people, or 0.09% of the national population. The emissions from the recycling of mercury-containing bulbs in Cumberland County, ME were estimated by the following:

$$0.6 \text{ lbs. mercury emissions} \times 0.091\% = 0.00057 \text{ lbs. mercury emissions}$$

### *Puerto Rico and US Virgin Islands Emissions Calculations*

Since insufficient data exists to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in pounds for these two Florida counties are divided by their respective populations creating a lb per capita emission factor. For each Puerto Rico and US Virgin Island county, the lb per capita

emission factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

## **Batteries**

Mercury use in batteries has decreased from a peak of 1,000 tons per year in the early 1980s (USGS 2005) to less than one ton in the mid-1990s (Leopold 2002). The Mercury-Containing and Rechargeable Battery Management Act of 1996 (P.L. 104-142) phased out the use of most types of mercury containing batteries. The batteries that were manufactured before this statute was enacted are not expected to still be in use. In addition, the amount of mercury emissions to the air from batteries prior to disposal is also minimal. Therefore no mercury emissions are expected to be emitted to the air from batteries in 2014.

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