
INTEROFFICE MEMORANDUM

TO: AIR ENGINEERING DIVISION, AIR ENFORCEMENT DIVISION
FROM: JAIMESON SINCLAIR, DIRECTOR, AIR ENGINEERING DIVISION
SUBJECT: DEFAULT MERCURY EMISSIONS FACTORS FOR PERMIT REVIEWS
DATE: MAY 8, 2019

The purpose of this memorandum is to standardize the emissions factors and methodology used by the Bureau in permit application reviews to evaluate mercury emissions from the cremation of human remains. A permit applicant's use of the emissions factors and methodology specified herein to make the applicable demonstrations required pursuant to RCSA Subsection 22a-174-3a(d) are presumed to be satisfactory to the Commissioner.

Mercury emissions from the cremation of human remains are assumed to result from the dental amalgam in the deceased that are cremated¹. The emissions factors presented here are the result of a material balance approach that asserts that the mercury in amalgam dental fillings in the deceased all vaporizes and is emitted. The amount of amalgam fillings and consequently mercury in the deceased is based on national health survey data regarding the prevalence of mercury amalgam fillings in various age groups, CT specific death statistics by age group, and the American Dental Association estimate of the average mercury content of amalgam fillings (i.e. 45% by weight).

Because mercury emissions vary significantly between individual cremations (due primarily to differences in the number and size of amalgam fillings between individuals), this material balance approach, which uses methods adopted by the Bay Area Air Quality Management District (BAAQMD) in 2012, is preferable to the use of an emission factor derived from results of very few source tests [e.g. EPA WebFIRE mercury emission factor (1992 emissions test of a single crematory unit) or California Air Resource Board California Air Toxic Emission Factors (1998 emissions test of a single crematory unit)]. Without knowing the amount of mercury in the deceased prior to conducting emissions test, the results provide little value to the development of a broadly applicable means of estimating emissions of mercury from human cremation. The emissions factors presented herein provide a conservative estimate of the weighted average amount of dental amalgam in the deceased in Connecticut. These factors show good agreement with the mercury emissions factors contained in BAAQMD's Permit Handbook, Section 11.6 Crematories (revised June 6, 2017)² and the quantity of mercury in both human subjects and cadavers, observed by researchers at the University of Minnesota in 2015³.

Mercury readily vaporizes at the high temperatures at which cremations occur.⁴ Excessive exposure to mercury vapor can result in adverse health impacts and the deposition of mercury and mercury compounds can negatively impact the environment.

¹ Mercury Emissions from the Cremation of Human Remains September 24, 2012
<http://www.baaqmd.gov/~media/files/engineering/permit-handbook/baaqmd-permit-handbook.pdf>

² Permit Handbook, Bay Area Air Quality Management District, Engineering Division
<http://www.baaqmd.gov/~media/files/engineering/permit-handbook/baaqmd-permit-handbook.pdf>

³ Quantifying Mercury Emissions Resulting From Cremation of Dental Amalgam in Minnesota September 2015,
<https://www.pca.state.mn.us/sites/default/files/eq-ci2-07a.pdf>

⁴ Mercury Emissions from the Cremation of Human Remains September 24, 2012
<http://www.baaqmd.gov/~media/files/engineering/permit-handbook/baaqmd-permit-handbook.pdf>

Mercury vapor is a Hazardous Air Pollutants listed in RCSA Section 22a-174-29. Pursuant to RCSA Subsection 22a-174-3a(d)(3) an applicant for a permit shall demonstrate, to the Commissioner's satisfaction, compliance with RCSA Section 22a-174-29. Pursuant to RCSA Subsections 22a-174-29(b)(2) and 22a-174-29(b)(6), the owner and operator of a crematory shall comply with the Maximum Allowable Stack Concentration for all hazardous air pollutants listed in RCSA Section 22a-174-29. A permit applicant's use of the emissions factors and methodology specified herein to demonstrate compliance with RCSA Section 22a-174-29 for emissions of mercury vapor are presumed to be satisfactory to the Commissioner. The use of other methods may require additional support and review to satisfy the Commissioner and could prolong permit application processing timeframes.

Emissions Factors:

For the purposes of estimating emissions of mercury from the cremation of human remains the following emissions factors are presumed satisfactory to the Commissioner for performing the demonstrations required in accordance with RCSA Subsection 22a-174-3a(d)(3):

Table 1 – Mercury Emissions Factors for Cremation of Human Remains	
Maximum Emission Factor	Average Emission Factor
0.013 lb. Hg/body	0.0034 lb. Hg/body

For air permitting purposes, the average represents the mean value of the anticipated amount of mercury found in the deceased and should be used when evaluating long-term (i.e. > 1 hr) actual emissions of mercury from the cremation of human remains. The maximum represents the infrequent occurrence of a deceased individual containing far more than the average amount of dental amalgam and should be used when evaluating short-term, episodic (i.e. <=1 hr), worst case actual emissions of mercury as described below.

Emissions Factor Use:

Cremation can be a batch operation, ranging in time from approximately 1-4 hours, depending on the size of the charge and the design of the cremation unit. Many new cremation unit designs can process a typical charge within an hour of the cremation cycle beginning. In a worst case mercury emission scenario, the deceased individual will contain the maximum amount of mercury and all of that mercury is vaporized and emitted within 1 hour of the cremation cycle beginning. The applicant for an air permit should compare the exhaust concentration of mercury vapor resulting from cremating a body in the span of 1 hour and using the maximum mercury emission factor to the Maximum Allowable Stack Concentration for mercury vapor calculated in accordance with RCSA Subsection 22a-174-29(c), adjusted in accordance with RCSA Subsection 22a-174-29(i) where T= 1 hour.

Advances in crematory design, processing speed, and ash handling equipment have become such that the operations of some newer cremation units are virtually continuous. These units can process several deceased in the span of 8 hours. The applicant for an air permit should also compare the exhaust concentration of mercury vapor resulting from cremating continuously for 8 hours using the average emissions factor and the maximum design processing rate of the cremation unit to the MASC for mercury vapor calculated in accordance with RCSA Subsection 22a-174-29(c).

If both comparisons prove that exhaust concentrations are less than the respective MASC calculations then the applicant shall have demonstrated to the Commissioner's satisfaction that emissions of mercury vapor from the cremation unit will comply with the applicable mercury vapor MASC as required pursuant to RCSA Subsection 22a-174-3a(d)(3)(M).

If either or both comparisons prove exhaust concentrations exceed the respective mercury vapor MASCs, then, in order, to obtain a permit the applicant must select one or more of the following options:

1. Relocating the unit;
2. Reducing the number of charges processed within a given amount of time;
3. Installing mercury emissions control equipment to reduce the rate of mercury emissions; or
4. Supplying alternate methods of quantifying mercury emissions from the unit that are satisfactory to the Commissioner to

The option(s) submitted must demonstrate to the Commissioner's satisfaction that the operation of the unit will comply with the MASC for mercury vapor as required pursuant to RCSA Subsection 22a-174-3a(d)(3)(M)

Note: When using the emissions factors contained in this memorandum for the types of cremation units commonly proposed for operation in Connecticut, an applicant would need to locate the stack exit from the proposed cremation unit, at least, 155 feet from the nearest property boundary in order for the unit to comply with MASC as required pursuant to RCSA Subsection 22a-174-3a(d)(3)(M)

The methodology used to derive the emissions factors presented herein duplicates work performed by the BAAQMD in 2012 in the report: *Mercury Emissions from the Cremation of Human Remains September 24, 2012*. The method uses information on restored teeth surfaces published in the CDC's National Health and Nutrition Examination Surveys (NHANES), on the weight of amalgam in tooth restorations published in the Journal of the Canadian Dental Association, and estimates from the American Dental Association that the mercury content of dental amalgam is 45% by weight. The principal difference between our derivation of emissions factors and BAAQMD, is the substitution of Connecticut specific death rates for the most recent 5 years available from the Connecticut Department of Public Health⁵ to determine the weighted average quantity of mercury in the deceased. Table 2 shows the resulting age groups, the number of individuals examined in the age group, the 95th percentile and average results from the NHANES study, the fraction of deaths in Connecticut, the weighted values (NHANES value multiplied by the fraction of deaths in CT) and the summed weighted values that represent the results for the deceased.

⁵ http://www.ct.gov/dph/lib/dph/hisr/xls/births_2008-2010_statanalyses.xlsx Table 9

Age Group	# of individuals in age group ⁶	Dental amalgam in NHANES individual at 95%-tile, grams	Average dental Amalgam in NHANES individual, grams	Fraction of Deaths in CT, 5 yr average	Weighted dental amalgam in individual at 95%,grams	Weighted average dental amalgam in individual, grams
Over 85	469	13.23	2.96	0.402	5.314	1.189
75-84	1407	14.33	3.65	0.239	3.421	0.871
65-74	1942	14.73	3.78	0.143	2.110	0.541
55-64	1907	14.94	4.32	0.104	1.557	0.450
45-54	2162	13.47	4.31	0.060	0.809	0.259
35-44	2435	10.40	3.29	0.021	0.223	0.070
25-34	2512	7.39	2.23	0.013	0.097	0.029
15-24	5643	4.62	1.07	0.009	0.040	0.009
5-14	6523	3.66	0.72	0.002	0.006	0.001
Under 5	2045	0.49	0.16	0.007	0.004	0.001
Sum for Dental Amalgam in deceased at the 95%-tile, grams					13.58	
Sum for Average Dental Amalgam in deceased, grams						3.422

The Maximum Emission Factor is based on the amount of dental amalgam present in the deceased representing the highest amount at the 95th percentile. The Average Emission Factor is based on the average amount of dental amalgam present in the deceased. Using a dental amalgam mercury content of 45 weight percent, estimated mercury emissions factors for human cremation for use in air permitting calculations are presented in Table 3.

Maximum (95%-tile)	6.111 grams/ body	0.013 lb./body
Average	1.54 gams/ body	0.0034 lb./body

⁶ NNAHNES data

These estimates are assumed to be conservative for the same reasons cited by BAAQMD in its 2012 report, principally.

- a. All tooth restorations in the NHANES studies were assumed to be amalgam, while recent dental practice also involves use of mercury free composites or other materials for aesthetic and other reasons.
- b. It is assumed that none of the mercury in the dental amalgam is lost over time, while data suggests that mercury vapor from amalgam restorations is released into the oral cavity over time.
- c. Dental data suggests a decline in the need for dental restoration and an associated decline in mercury dental amalgam insertions over recent years for a variety of reasons.

Comparison with Other Estimates of Mercury Emissions from human cremations

Table 4 shows a comparison of mercury emissions estimates from human cremations from this memorandum, BAAQMD's report, and a University of Minnesota study from 2015⁷

Connecticut	BAAQMD	University of Minnesota ⁸
Maximum: 6.1 gr/body	Maximum: 6.1 gr/body	Maximum: not specified
Average: 1.54 gr/body	Average: 1.56 gr/body	Average: 2.3 gr/body, live subjects Average: 1.5 gr/body, cadavers

Table 4 shows strong agreement with emissions factors derived from NHANES data by Connecticut and BAAQMD. Furthermore, there is agreement between the average emissions factors derived by Connecticut and BAAQMD and the average amount of mercury actually observed researchers at the University of Minnesota in the bodies of cadavers.

It should be noted that very few emissions tests for mercury have been performed and witnessed by air licensing agencies. There is disagreement as to whether or not emissions tests are an appropriate means for deriving an emission factor for mercury emissions from crematories. There is broad agreement that any mercury in the body being cremated will be emitted during cremation. However, the amount of mercury in the body being cremated during the few tests was not known prior to the test. Conceivably, in instances where emissions factors from stack test show very low mercury emissions it may be coincident with a body that did not have any amalgam fillings. Alternatively, a high result may be coincident with a body that contained an amount of amalgam fillings that significantly exceeds the norm. Table 5 shows a comparison of the mercury emissions estimates for human cremation derived in this memorandum and emissions factors for human cremation derived by emissions tests.

Emission Factor Source	Factor (lb./body)	Comments

⁷ Quantifying Mercury Emissions Resulting from the Cremation of Dental Amalgam in Minnesota, <https://www.pca.state.mn.us/sites/default/files/aq-ei2-07a.pdf>

⁸ University of Minnesota study only addresses individuals between the ages of 63 and 79 years old.

CT	Maximum: 0.013 Average: 0.0034	Derivation based on NHANES data as described in this memorandum
California Air Resources Board California Toxic Emission Factors ⁹	Maximum: 0.005 Average: 0.0048	Single emissions test at undisclosed propane fired crematory c. 1998. Amount of dental amalgam present in the deceased unknown.
EPA WebFIRE ¹⁰	Average: 0.0033	Single emissions test at undisclosed propane fired crematory c. 1992. Amount of dental amalgam present in the deceased unknown.
Woodlawn Cemetery ¹¹	Average: 0.001	Average of 11 tests performed at Wood Lawn Cemetery on undisclosed natural gas fired crematory c.1998. Amount of dental amalgam present in the deceased unknown.

The Department's average emissions factors show good agreement with EPA and CARB emissions factors that have been used in prior air permitting cases. As stated, without knowing the amount of mercury in the deceased prior to cremation, stack tests provide little value in developing an emissions factor that could be broadly applied to estimating emissions of mercury from human cremation. However, Table 5 suffices to illustrate that the Department's derived emissions factors are not significantly different from the emissions observed during some tests and stack test based emissions factors that have been used in previous air permitting cases, nationwide. Which supports the position that the Department's emissions factors are conservative but not unreasonable.

⁹ https://www.arb.ca.gov/app/emsinv/catef_form.html system type= crematory

¹⁰ <https://cfpub.epa.gov/webfire/index.cfm?action=fire.SearchEmissionFactors> using Simple Search input "crematory"

¹¹ <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100FVCP.PDF?Dockey=P100FVCP.PDF>

