NEW YORK STATE | Department of Health

Health-Based Air Concentrations for Mercury Vapor

Health-based Guidance Values (Air Concentrations) for Mercury Vapor

Type of Value	Agency (Date)	Value	Exposure
Occupational Standard or Guideline			
Regulation-PEL[1]	OSHA[2] (1976)	100 mcg/m^3	8-Hour TWA[3]
Guideline-REL[4]	NIOSH[5] (1973)	50 mcg/m^3	10-Hour TWA
Guideline-TLV[6]	ACGIH[7] (1991)	25 mcg/m^3	8-Hour TWA
Non-Occupational Guideline			
Minimal Risk Level (MRL)[8]	ATSDR[9] (1999)	0.2 mcg/m^3	Chronic inhalation
Reference Concentration (RfC)[10]	US EPA[11] (1995)	0.3 mcg/m^3	Chronic inhalation
Chronic CA REL[12]	CA EPA[13] (2008)	0.03 mcg/m^3	Chronic inhalation
8-Hour CA REL[14]	CA EPA (2008)	0.06 mcg/m^3	Intermittent 8-Hour inhalation
Acute CA REL[15]	CA EPA (2008)	0.6 mcg/m^3	Intermittent 1-Hour inhalation

mcg/m3: microgram mercury per cubic meter of air.
1 milligram (mg) = 1,000 micrograms (mcg) = 1,000,000 nanograms (ng)

[1] A Permissible Exposure Limit (PEL) must not be exceeded during any 8-hour workshift of a 40 hour work week.
[2] Occupational Safety and Health Administration (OSHA)
[3] Time Weighted Average (TWA): the air concentration averaged over a specific period of time.
[4] Recommended Exposure Limit (REL): average air concentration for a 10-hour workday.
[5] National Institute for Occupational Safety and Health (NIOSH)
[6] Threshold Limit Value (TLV): the air concentration that nearly all workers may routinely be exposed to during 8-hour workdays of a 40 hour work week without having adverse health effects.
[7] American Conference of Governmental Industrial Hygienists (ACGIH)
[8] A Minimal Risk Level (MRL) is an estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse, non-cancer health effects over a specified route and duration of exposure.
[9] Agency for Toxic Substances and Disease Registry
[10] A Reference Concentration (RfC) is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
[11] United States Environmental Protection Agency

[12] A Chronic CA REL (California Reference Exposure Level) is a concentration at or below which adverse health effects are not likely to occur in the general human population exposed continuously over a lifetime. [http://www.oehha.ca.gov/air/ hot_spots/2008/NoncancerTSD_final.pdf]
[13] California Environmental Protection Agency
[14] An 8-hour CA REL is a concentration at or below which adverse health effects are not likely to occur in the general human population with intermittent exposures of eight hours per day, up to 7 days per week.
[15] An Acute CA REL is an exposure that is not likely to cause adverse effects in a human population, including sensitive subgroups (such as infants and children), exposed to that concentration for one hour on an intermittent basis.

Derivation of Non-occupational, Chronic Health-based Guidance Values

Minimal Risk Level (MRL) (Agency for Toxic Substances and Disease Registry (ATSDR)):

The chronic inhalation MRL is based on measurements of tremor in men occupationally exposed to mercury (Fawer et al., 1983; ATSDR, 1999; US EPA, 1995). The study population consisted of 26 exposed workers, and a control group of 25 workers from the same factories who had never been occupationally exposed to mercury. The average duration of mercury exposure was 15.3 ± 2.6 years (range 1-41 years). At the time of the study, the concentration of mercury in work area air (as measured by personal air samplers for individual workers) was 0.026 ± 0.004 mg/m3 (8-hr TWA). Historical air concentrations were not known, but some data suggested they might have been higher than this value. The measure of effect was a statistical index value, designated M2, which combined the peak frequency of tremors with the amplitude of the tremors. For a hand at rest, M2 was somewhat greater for exposed compared to unexposed workers, but not significantly so ($p>0.05$). However, for a hand carrying a weight, the increase in tremor associated with the weight was greater for exposed than for unexposed workers ($p<0.002$). The increased tremor in a hand carrying a weight correlated with the duration of exposure to mercury and also with the level of mercury in urine ($p<0.01$) (a biomarker of exposure to mercury), but was not associated with age (Fawer et al., 1983).

The average measured air concentration was used as the Lowest Observed Adverse Effect Level (LOAEL) for tremors. The intermittent workplace exposure was adjusted by conversion to an equivalent continuous exposure:

$$0.026\ mg/m^3\ X\ (8\ hrs/24\ hrs)\ X\ (5\ days/7\ days) = 0.0062\ mg/m^3 = 6.2\ mcg/m^3$$

Dividing this adjusted LOAEL by an uncertainty factor (UF) of 30 (3x for use of a minimal LOAEL rather than a No Observed Adverse Effect Level [NOAEL] and 10x to account for variation within the human population) results in a minimal risk level (MRL) of 0.2 mcg/m^3.

$$6.2\ mcg/m^3\ /30 = 0.2\ mcg/m^3$$

For more detail see: http://www.atsdr.cdc.gov/toxprofiles/tp46-a.pdf

Reference Concentration (RfC) (US Environmental Protection Agency (US EPA)):

US EPA also used the Fawer et al. (1983) study as the primary basis for a chronic mercury vapor RfC. However, they supported this study with LOAELs derived from five other studies (Piikivi and Tolonen, 1989; Piikivi and Hanninen, 1989; Piikivi, 1989; Ngim et al., 1992; Liang et al., 1993) that showed subtle neurotoxic effects in workers exposed to mercury vapor. The LOAELs estimated in these 5 studies bracketed the LOAEL from the Fawer et al. (1983), ranging from 0.023 to 0.030 mg/m3. The average duration of exposure for a total of 308 workers was 12.0 years. EPA estimated the (weighted) average LOAEL from these 6 studies to be 0.025 mg/m^3 (8-hr-TWA).

Using the 0.025 mg/m^3 TWA and adjusting by conversion from occupational conditions (10 m^3/ workday x 5 days/week) to continuous exposure (20 m^3/day x 7 days/week), EPA derived an adjusted LOAEL of 0.009 mg/m^3 for continuous exposure.

$$0.025\ mg/m^3\ x\ [10\ m3\ /20m^3]\ x\ [5\ days/7\ days] = 0.0089\ mg/m^3 = 9\ mcg/m^3$$

EPA applied an uncertainty factor of 30 (10-fold factor for combined sensitive human subgroups and using a LOAEL instead of a NOAEL, and 3-fold factor for lack of an adequate database):

$$RfC = 9\ mcg/m^3 / 30 = 0.3\ mcg/m^3$$

For more detail see http://www.epa.gov/iris/subst/0370.htm

Chronic Recommended Exposure Limit (REL) (California EPA):

The California Environmental Protection Agency (CA EPA, 2008) determined a chronic REL for elemental mercury using five of the six studies used by US EPA (Liang et al, 1993, was not used), with the same adjusted LOAEL (9 mcg/m^3). However, CA EPA applied an uncertainty factor of 300 (30–fold factor for intra-species variability and a 10-fold factor for use of a LOAEL). This gives a chronic REL of

$$9.0\ mcg/m^3 /300 = 0.03\ mcg/m^3$$

For more detail see: http://www.oehha.ca.gov/air/allrels.html

8-Hour Recommended Exposure Limit (REL) (California EPA):

The California Environmental Protection Agency (CA EPA, 2008) determined an 8-hour REL for elemental mercury using five of the six studies used by US EPA (Liang et al, 1993 was not used), with an adjusted LOAEL (18 mcg/m3) accounting for exposure for 5 of 7 days per week. CA EPA applied an uncertainty factor of 300 (30–fold factor for intra-species variability and a 10-fold factor for use of a LOAEL). This gives an 8-hour REL of

$$18.0\ mcg/m^3 /300 = 0.06\ mcg/m^3$$

For more detail see: http://www.oehha.ca.gov/air/allrels.html

Derivation of Non-Occupational Acute Health-Based Guidance Value

Acute Recommended Exposure Limit (REL) (California EPA):

The Acute CA REL for mercury vapor is based on the Danielsson (1993) study. In this study, pregnant rats were exposed by inhalation for 8 days (gestation day 11-14 and 17-20), to clean air for 2 hr/day (controls) or to elemental mercury vapor at 1.8 mg/m3 for 1 hr/day (low dose) or 3 hr/day (high dose). There was no apparent toxicity to either the dam or the pups, as indicated by no differences (compared to controls) in maternal body weight or body weight gain, or in litter size, pup weight, general appearance, or achievement of developmental milestones (e.g. eye opening).

However, differences were noted when young pups from mothers that had been exposed either to clean air or to mercury vapor were subjected to behavioral testing. The differences were seen at both the high dose (3 hr/day exposure) and at the low dose (1 hr/day exposure).

- The pups exposed prenatally to mercury vapor were somewhat hypoactive (less active) at 3 months of age ($p<0.01$) than the pups exposed to clean air, but not at 14 months. Differences were not consistent, or statistically significantly different between the high and low dose groups (i.e., no evidence of a dose-response relationship).
- At 4 months, the prenatally exposed pups were slower in learning a task in the radial arm maze. This effect was statistically greater for both the low dose ($p<0.05$) and the high dose ($p<0.01$) groups when compared to the control group.
- At 7 months, the low and high dose group rats showed deficits in becoming habituated (accustomed) to a novel environment compared to the control group. This effect increased with dose (low dose group, $p<0.05$; high dose group, $p<0.01$) (Danielsson et al., 1993).

Based on these data, the Low Observed Effect Concentration (LOEC) for neurodevelopmental mercury toxicity in rats was determined to be 1.8 mg/m^3. A No Observed Effect Concentration (NOEC) was not identified (CA EPA, 1999).

An uncertainty factor of 3000 was applied to the LOEC of 1.8 mg/m3 (10-fold factor for use of a LOEC rather than a NOEC, a 30 fold factor for interspecies variability and a 10-fold factor for intra-species variability) resulting in an acute 1-hour REL of

$$1.8\ mg/m^3/3000 = 0.0006\ mg/m^3\ (0.6\ mcg/m^3).$$

For more detail see: http://www.oehha.ca.gov/air/allrels.html

References:

- ACGIH (American Conference of Governmental Industrial Hygienists). 1994. Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. Cited by NIOSH.
- ATSDR (Agency for Toxic Substance and Disease Registry). 1999. Toxicological Profile for Mercury. United States Department of Health and Human Services. Public Health Service. Accessed 9/28/2016: http://www.atsdr.cdc.gov/toxprofiles/tp46-a.pdf
- CA EPA (California Environmental Protection Agency). 2016. Determination of Acute Reference Exposure Levels for Airborne Toxicants. Sacramento CA: Office of Environmental Health Assessment, California Environmental Protection Agency. Accessed 9/28/2016: http://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary
- CA EPA (California Environmental Protection Agency). 2008. Technical Support document for the Derivation of Noncancer Reference Exposure Levels. Sacramento CA: Office of Environmental Health Assessment, California Environmental Protection Agency. Accessed 9/28/2016: http://oehha.ca.gov/air/crnr/noticeadoption-air-toxics-hot-spots-program-technical-support-document-derivation
- CA EPA (California Environmental Protection Agency). 2016. Technical Support document for the Derivation of Noncancer Reference Exposure Levels, Appendix D1, Mercury Reference Exposure Levels. Oakland CA: Office of Environmental Health Assessment, California Environmental Protection Agency. Accessed 9/28/2016: http://www.oehha.ca.gov/air/allrels.html
- Danielsson BRG, Fredriksson A, Dahlgren L et al. 1993. Behavioral effects of prenatal metallic mercury inhalation exposure in rats. Neurotoxicol Teratol. 15:391-396.
- Fawer RF, DeRibaupierre U, Guillemin MP, Berode M and Lobe M. 1983. Measurement of hand tremor induced by industrial exposure to metallic mercury. Brit J Ind Med. 40:204-208.
- Liang Y-X, Sun R-K, Sun H, Chen Z-Q and Li L-H. 1993. Psychological effects of low exposure to mercury vapor: Application of a computer-administered neurobehavioral evaluation system. Environ Res. 60:320-327.
- Ngim CH, Foo SC, Boey KW and Jeyaratnam J. 1992. Chronic neurobehavioral effects of elemental mercury in dentists. Brit J Ind Med. 49:782-790.
- NIOSH (National Institute of Occupational Safety and Health). 2016. NIOSH Pocket Guide to Chemical Hazards. Accessed 9/28/2016: http://www.cdc.gov/niosh/npg/npgd0383.html
- OSHA (Occupational Safety and Health Administration). 2016. Accessed 9/28/2016. https://www.osha.gov/SLTC/mercury/index.html
- Piikivi L. 1989. Cardiovascular reflexes and low long-term exposure to mercury vapor. Int Arch Occup Environ Health. 61:391-395.
- Piikivi L and Hanninen H. 1989. Subjective symptoms and psychological performance of chlorine-alkali workers. Scand J Work Environ Health. 15:69-74.
- Piikivi L and Tolonen U. 1989. EEG findings in chlor-alkali workers subjected to low long term exposure to mercury vapor. Brit J Ind Med. 46:370-375.
- US EPA (United States Environmental Protection Agency). 1995. Integrated Risk Information System (IRIS). Summary for Elemental Mercury. Accessed 9/28/2016. http://www.epa.gov/iris
- US EPA (United States Environmental Protection Agency). 1994. Methods for derivation of inhalation reference concentrations and application of inhalation dosimetry. Environmental Criteria and Assessment. Office of Health and Environmental Assessment. Office of Research and Development. Research Triangle Park, NC. EPA/600/8-90/066F. Oct 1994. Accessed 2/23/2018. https://www.epa.gov/risk/methodsderivation-inhalation-reference-concentrations-and-application-inhalation-dosimetry