

EPA's Modeled Annual Average Ambient Concentrations of Cr(VI) at Monitoring Sites are Far Higher than Actual Monitored Concentrations at Those Monitors

There is something systematically wrong with EPA's process for estimating hexavalent chromium emissions and using dispersion modeling to predict resulting annual average concentrations at monitoring sites. Across those higher-risk sites at which Cr(VI) concentrations have been both modeled and monitored, EPA's modeled/predicted concentrations are 3 to 5 times too high relative to actual monitoring results. It is not clear exactly where in EPA's sequence of modeling steps the most significant errors occur; we find significant problems at multiple points in both EPA's emission estimates and dispersion modeling.

In 2007, EPA completed an analysis of information on hexavalent chromium as part of the Urban Air Toxics Monitoring Program (UATMP).¹ This 2007 study remains EPA's only substantial analysis addressing ambient concentrations of hexavalent chromium. In the report, EPA compiled the results of special ambient air monitoring for hexavalent chromium conducted at 22 UATMP sites and one Hurricane Katrina site during 2005. The monitoring sites represent a wide variety of conditions. The 23 sites ranged from highly urban (e.g., Detroit, Chicago and Seattle) to near-downwind of an urban area (Atlanta) to on-site heavy industrial (Sloss Industries outside Birmingham, AL, with a metals plant and coke ovens) to residential (Oregon) and rural/background (Wisconsin, Alabama).

Each site was intended to be monitored for hexavalent chromium every 6 or 12 days during the entire year, but this was not achieved at all sites. Monitoring began late or ended early in the year at some sites, and some monitoring dates were missed for varying reasons. In total, more than 1200 hexavalent chromium concentrations (including some collocated samples) were collected across the 23 sites. EPA calculated a daily average concentration at each site as the average concentration of all detects. EPA calculated an annual average concentration at each site where monitoring began no later than February and ended no earlier than November, and non-detects were averaged into the annual average calculations at one-half the method detection limit (MDL). For each site where it was calculated, the annual average was thus always less than or equal to the daily average due to the inclusion of non-detects in the annual average calculations at one-half the MDL.

In addition to compiling daily and annual average hexavalent chromium concentrations for the monitoring sites, in the report EPA also compared the concentrations of Cr(VI) that were modeled in the Agency's National Air Toxics Assessment (NATA) risk analysis against the actual UATMP monitored concentrations at these sites. EPA compared the annual average modeled concentration of hexavalent chromium at the centroid of the Census Tract within which each UATMP monitor was located against the calculated annual average monitored concentration at the corresponding site. Although EPA did not characterize the results in this manner, the results were striking -- across all the higher-modeled-risk UATMP sites, EPA's predicted ambient concentrations of hexavalent chromium were 3 to 5 times higher than the actual monitored concentrations:

¹ U.S. EPA. 2005 Urban Air Toxics Monitoring Program (UATMP) -- Hexavalent Chromium. Final Report. February, 2007.

- Across the UATMP sites for which projected lifetime cancer risks from hexavalent chromium were 1×10^{-6} or more, EPA's modeled annual average ambient concentrations exceeded the actual monitored annual average concentrations by a factor of more than 5.
- The degree to which EPA's modeling overestimated actual monitored Cr(VI) concentrations declines as one looks at UATMP sites posing progressively lower-risks. Across all UATMP sites for which modeled risks exceeded 0.5×10^{-6} , modeled concentrations exceeded monitored concentrations by an average factor of about 4. Across the UATMP sites for which modeled risks exceeded 0.3×10^{-6} , modeled concentrations exceeded monitored concentrations by an average factor of about 3.5. Across the UATMP sites for which modeled risks were less than 0.3×10^{-6} , modeled concentrations were typically slightly less than monitored concentrations.

These results are shown in the tables below.

EPA Modeling for Cr(VI) Greatly Over-Estimates Actual Ambient Concentrations

2005 Hex Chrome UATMP Monitoring Site Location	Monitored Annual Average* (ng/m ³)	Census Tract ID	NATA-Modeled Concentration (ng/m ³)	NATA-Modeled Cancer Risk (x 10 ⁻⁶)	Ratio: Modeled vs. Actual LTA Cr(VI) Concentration
Seattle, WA	0.048	53033010000	0.621	7.46	12.94
St Louis, MO	0.033	29510109700	0.195	2.34	5.91
Detroit, MI	0.057	26163573500	0.138	1.65	2.42
Providence, RI	0.019	44007000400	0.117	1.41	6.16
North Birmingham, AL	0.035	01073000800	0.090	1.08	2.57
Birmingham, AL (Stloss Industries)	0.035	01073005500	0.083	1.00	2.37
Sydney, FL (rural, nr Tampa)	0.027	12057012204	0.083	1.00	3.07
East Thomas, AL (Birmingham)	0.033	01073001200	0.076	0.91	2.30
Northbrook, IL (Chicago)	0.027	17031801500	0.062	0.74	2.30
Bountiful, UT (Ogden)	0.022	49011126600	0.057	0.68	2.59
Providence, AL (rural)	0.011	01073014102	0.055	0.66	5.10
Boston, MA	0.057	25025080400	0.045	0.54	0.79
Decatur, GA (downwind Atlanta)	0.030	13089023404	0.040	0.48	1.33
Washington, DC	0.026	11001003301	0.032	0.38	1.22
Gulfport, MS	0.017	28047001700	0.026	0.31	1.54

* Annual averages shown include 6 sites where EPA calculated only daily averages.

Across all hexavalent chromium UATMP sites where EPA calculated an annual average, this annual avg. = 0.67 daily avg.

For the 6 sites where EPA didn't calculate an annual avg., we estimated annual avg. as 0.67 x the site's daily average

Average Ratio: Modeled vs. Actual Cr(VI) Concentration		
7 Sites w/modeled risk $\geq 1 \times 10^{-6}$	5 Sites w/modeled risk between 0.5 and 1.0×10^{-6}	3 Sites w/modeled risk between 0.3 and 0.5×10^{-6}
5.06	2.62	1.37

7 Sites w/modeled risk $\geq 1 \times 10^{-6}$	12 Sites w/modeled risk $> 0.5 \times 10^{-6}$	15 Sites w/modeled risk $> 0.3 \times 10^{-6}$
5.06	4.04	3.51

These results suggest that EPA's emissions and dispersion modeling for hexavalent chromium is systematically biased high, leading to greatly over-estimating ambient concentrations (and risks) at those sites where higher concentrations are modeled.

EPA's 2005 NATA risk modeling (analyzed above) and EPA's RTR analyses for maximum individual risks (MIR) employ nearly identical modeling procedures. EPA's MIR emissions and dispersion modeling for hexavalent chromium for the electroplating/anodizing RTR is very likely to be biased high for higher-risk sites in a similar manner as is the NATA modeling.

Nearly Identical Modeling Procedures Used for Both NATA and RTR

Both analyses:

- Start with NEI estimates of HAP emissions and emission point characteristics (including identical default assumptions regarding stack height, exit velocity, etc. when information is not available) for the relevant source categories;
- Use HEM for dispersion and risk modeling, including: 1) accessing the same meteorology data; 2) running the model in a mode that does not account for reduction and wet/dry deposition of Cr(VI), etc.
- Estimate risks for HAPs based on the IRIS toxicity values for each HAP and based on EPA's standard assumptions about exposure constants, body weight, 70-year lifetime, etc..

Some or all of the following factors likely account for what we believe to be EPA's badly overestimated hexavalent chromium concentrations in RTR modeling of MIR and population risks at sites around chromium electroplating/anodizing facilities:

- EPA has overestimated Cr(VI) emissions. Based on the limited information available on the changes that EPA may have made to its risk modeling since the 10/20/10 proposal, EPA's errors include the following:
 - EPA has facility-specific emissions estimates for only 166 of 1,770 facilities in the electroplating/anodizing source categories. 1,604 facilities are modeled as "model plants".
 - EPA estimated emission rates and operating hours/amp-hours for each category of model plant based on 1990-era ICR, which does not reflect: 1) Improvements in controls and control performance over time, including improvements due to the original MACT, OSHA requirements, and State requirements; 2) Facility closures and reduced operating hours due to the recession.
 - EPA chose high-end (e.g., 94th percentile) rather than mean or median emission rates as representing the rates for each category of model plant.
 - EPA made worst-case default assumptions in choosing which sort of model plant to use in representing an individual facility about which information on size and processes is lacking. All facilities of unknown size (all of the 1,604 facilities) are assumed to be "large" rather than "medium" or "small". All facilities for which process information is lacking (about half of the 1,604 facilities) are assumed to

- conduct hard chrome electroplating (highest emission rate) rather than decorative chrome or anodizing (much lower emission rates).
- EPA assumed that 100% of every facility's chromium emissions is hexavalent, despite evidence to the contrary (e.g., Shin and Pak (2000) found fairly rapid reduction of hexavalent chromium in electroplating mists to trivalent -- hex chrome = 100% of total chrome immediately after mist generation, but declines to 85% after 1 hour, 77% after 3 hours, etc.)
 - In nearly every instance when we have investigated actual electroplating/anodizing facility emissions, they were substantially lower than EPA's estimate.
 - EPA's default assumptions regarding stack height/diameter, exit velocity and temperature are all nearly worst case, and may be inaccurate.
- EPA appears to have overestimated the annual average ambient concentrations of hexavalent chromium that will result at locations around the facility, given that facility's emissions. EPA's errors:
 - Failure to run HEM/AERMOD in a mode that accounts for rapid reduction/reactivity of hexavalent chromium to trivalent. A study for CARB found an average half-life of 14.4 hours for Cr(VI) under common atmospheric conditions (Grohse, et al.. 1988).
 - Failure to run HEM/AERMOD in a mode that accounts for wet and dry deposition of Cr(VI) and plume depletion. (All Cr(VI) emitted from electroplating/anodizing facilities is in particulate/aerosol form and subject to deposition.)
 - Chose to run HEM/AERMOD in "rural" rather than "urban" mode, thereby simulating less mixing and less dispersion (thus higher concentrations and higher risks, particularly MIR) near emissions sources
 - Assumed 30 meter default distance from facility stack to property fenceline (where MIR risk modeling may begin). This is too small for some facilities.

Monitored Ambient Levels of Cr(VI) (Reflecting Emissions From All Sources, Not Just Electroplating/Anodizing) Are Lower than the Concentrations That EPA Projects Would Result at MIR Sites from Electroplating/Anodizing Emissions Alone

By definition the MIR around a source occurs only at the particular location near the source where ambient concentrations are the highest. It is unlikely that the relatively few locations around the country where ambient hexavalent chromium levels have been monitored include the sites that are points of MIR for hexavalent chromium sources. One would thus expect the concentrations of hexavalent chromium that actually exist at MIR sites to be higher than the concentrations that exist at most, if not all, sites at which monitoring has actually occurred.

Nevertheless, it seems incorrect for EPA to model theoretical concentrations of hexavalent chromium at MIR sites due to electroplating emissions alone that are higher than any observed actual ambient concentrations of hexavalent chromium, which reflect emissions from all source types, not just electroplating. After all, surface finishing accounts for less than 1% of total national emissions of hexavalent chromium and chromic acid, as estimated in the 2005 NEI (see attachment). How can EPA plausibly model ambient concentrations from a single source type that accounts for less than 1% of total emissions as being higher than the highest actual ambient concentrations that have been monitored, with the actual ambient concentrations presumably reflecting emissions from all source types?

According to EPA's modeling of electroplating facility emissions and dispersion, the estimated annual average concentrations of hexavalent chromium from electroplating sources at MIR sites are as follows (Note: I have back-calculated² EPA's estimated ambient concentrations at MIR sites from EPA's estimates of risks at MIR sites):

EPA's Modeled Ambient Concentration of Cr(VI) from Electroplating Facilities at MIR Sites

- **2.1 ng/m³** is the annual average hexavalent chromium concentration at the MIR site for the highest-risk electroplating facility. (MIR of $> 20 \times 10^{-6}$) *Note: we do not have the precise MIR value for this facility, so in these calculations we have assumed an MIR of 25×10^{-6} .*
- **1.5 ng/m³** is the annual average hexavalent chromium concentration at the MIR site for the second-highest-risk electroplating facility. (MIR of 18×10^{-6}).
- **0.83 ng/m³** or more are the annual average hexavalent chromium concentrations at the MIR sites for the 14 highest-risk electroplating facility. (According to EPA, 14 facilities pose MIR exceeding 10×10^{-6}).

At roughly 1 to 2 ng/m³, these annual average concentrations of hexavalent chromium that EPA models at MIR sites from electroplating facility emissions alone exceed the highest annual average concentrations of hexavalent chromium actually found at monitoring sites -- even though the actual monitored levels reflect Cr(VI) emissions from all sources, with all other sources responsible for at least 100 times the quantity of Cr(VI) emissions as electroplating facilities.

² EPA's estimated lifetime upper-bound excess cancer risk from hexavalent chromium exposure at 1 ug/m³ annual average concentration is 1.2×10^{-2} (IRIS). Hence MIR risk of 25×10^{-6} (MIR modeled by EPA for the highest risk electroplating facility, we think) implies an annual average hexavalent chromium concentration of 2.1 ng/m³ at the MIR site for that facility.

Hexavalent Chromium Monitoring Data

EPA: 2005 Urban Air Toxics Monitoring Program, special report on monitoring results for hexavalent chromium (2007).³

- 22 monitoring sites, some near the centers of heavily populated cities (e.g., Chicago, Seattle), while others were in more rural areas (e.g., Chesterfield, SC and Hazard, KY). Aim was to sample each site every 6 or 12 days during the year (for various reasons some of the sites did not meet this goal).
- Highest annual average level of Cr(VI) at any site was 0.06 ng/m³ (resulting in lifetime excess cancer risk at that location of 0.7×10^{-6}). Grand average annual concentration across all sites appears to be about 0.03 ng/m³ (corresponding to lifetime excess cancer risk of 0.35×10^{-6}).

CA: Available data for 2009 and 2010 from all CA monitoring sites with data on Cr(VI) (15+ sites each year).⁴

- Annual average level of Cr(VI) across all sites was 0.045 ng/m³. Highest quarterly average level of Cr(VI) at any site was 0.19 ng/m³ (124 quarterly averages, across 2 years and 15+ sites). This concentration corresponds to a lifetime excess cancer risk of about 2×10^{-6} .

TX: Data collected during 2007 - 2009 from four monitors near heavily industrialized sites (not electroplating).⁵

- Range of annual average Cr(VI) concentrations at three monitors was 0.1 to 0.2 ng/m³, while the range at the final site was <0.001 to 0.4 ng/m³.
- TX CEQ's conclusion from a review of EPA, CA and TX data on ambient levels of total chromium and hexavalent chromium: "Overall, the data reviewed on speciated chromium indicate that hexavalent chromium measured in ambient air makes up less than 10% of the total chromium, and the USEPA assumption (34% of total atmospheric chromium is hexavalent) is very conservative. Monitored data, while variable, is fairly consistent across data-sets. In other words, forms of chromium other than hexavalent typically make up more than 90% of measured ambient chromium levels."⁶

Conclusion: The highest annual average ambient Cr(VI) concentration observed at any site (and reflecting emissions from all source categories) among data from EPA, CA and TX was 0.4 ng/m³, much less than the concentrations of 1 - 2 ng/m³, modeled by EPA at MIR sites due to electroplating emissions alone. EPA's modeling results are not plausible.

³ U.S. EPA. 2005 Urban Air Toxics Monitoring Program (UATMP) -- Hexavalent Chromium. Final Report. February, 2007.

⁴ Available at: <http://www.arb.ca.gov/adam/toxics/statepages/cr6state.html>

⁵ Texas Commission on Environmental Quality. *Development Support Document: Chromium -- All Compounds Except Hexavalent Chromium*. Final, October 8, 2009.

⁶ *Ibid.*, p. 8.

Sources of Hexavalent Chromium and Chromic Acid Emissions, from 2005 NEI

Category Name	Pollutant	SOURCE	Emissions (tpy)	Surface Finishing
Waste Disposal	Chromium (VI)	POINT	0.821654087	
Indus Process - Metals	Chromium (VI)	POINT	0.028627013	
Indus Process - NEC	Chromium (VI)	NONPOINT	0.077337107	
Fuel Comb - Commercial/Institutional	Chromium (VI)	POINT	0.118779229	
Indus Process - Pulp & Paper	Chromium (VI)	POINT	1.787444328	
Construction	Chromium (VI)	POINT	0.00000201	
Non-Road Equipment - Gasoline	Chromium (VI)	NONROAD	0.239950808	
Fuel Comb - Commercial/Institutional	Chromium (VI)	NONPOINT	0.016080029	
Planes, Trains, & Ships	Chromium (VI)	NONROAD	0.284385395	
On-Road Vehicles - Diesel	Chromium (VI)	ONROAD	0.057693448	
On-Road Vehicles - Gasoline	Chromium (VI)	ONROAD	2.408814633	
Solvent - NEC	Chromium (VI)	POINT	2.5493E-06	
Indus Process - Petroleum Refineries	Chromium (VI)	POINT	0.008902453	
Fuel Comb - Industrial Boilers, ICES	Chromium (VI)	NONPOINT	0.084866356	
Fuel Comb - Industrial Boilers, ICES	Chromium (VI)	POINT	0.638748795	
Gas Stations	Chromium (VI)	NONPOINT	0	
Indus Process - NEC	Chromium (VI)	POINT	2.89629518	
Fuel Comb - Residential Fireplaces	Chromium (VI)	NONPOINT	0	
Indus Process - Oil & Gas Production	Chromium (VI)	POINT	0.009434548	
Graphic Arts	Chromium (VI)	POINT	0.001116606	
Surface Coating - Industrial	Chromium (VI)	POINT	0.129376394	0.129376
Indus Process - Chemical Manuf	Chromium (VI)	POINT	0.037271436	
Fuel Comb - Residential Fossil	Chromium (VI)	NONPOINT	0.01594207	
Indus Process - Storage & Transfer	Chromium (VI)	POINT	0.010721679	
Non-Road Equipment - Diesel	Chromium (VI)	NONROAD	0.002444313	
Waste Disposal - Open Burning	Chromium (VI)	POINT	0.002081	
Degreasing	Chromium (VI)	POINT	0.002530355	
Fuel Comb - Electric Utility	Chromium (VI)	POINT	27.28964883	
Indus Process - Cement Manuf	Chromium (VI)	POINT	0.007778636	
Fuel Comb - Electric Utility	Chromium (VI)	NONPOINT	0.000134024	
Gas Stations	Chromium (VI)	POINT	1.0899E-06	
Bulk Gasoline Terminals	Chromium (VI)	POINT	1.4091E-08	
Total for Cr (VI)			36.97806442	0.35%
Indus Process - Pulp & Paper	Chromic Acid (VI)	POINT	0.7559877	
Graphic Arts	Chromic Acid (VI)	POINT	0.0004	
Solvent - NEC	Chromic Acid (VI)	POINT	0.00001	
Indus Process - Storage & Transfer	Chromic Acid (VI)	POINT	0.006684777	
Degreasing	Chromic Acid (VI)	POINT	0.0023125	
Fuel Comb - Commercial/Institutional	Chromic Acid (VI)	POINT	0.003568565	
Surface Coating - Industrial	Chromic Acid (VI)	POINT	0.010849123	0.010849
Fuel Comb - Industrial Boilers, ICES	Chromic Acid (VI)	POINT	0.078880585	
Indus Process - Chemical Manuf	Chromic Acid (VI)	POINT	0.0001151	
Indus Process - NEC	Chromic Acid (VI)	POINT	0.40396068	
Fuel Comb - Electric Utility	Chromic Acid (VI)	POINT	0.377214387	
Total for Chromic Acid (VI)			1.639983416	0.66%

Note: NEI likely omits many sources of hexavalent chromium emissions in all of the above categories. A reasonable estimate of current average annual Cr(VI) emissions from an electroplating or anodizing source might be about 0.5 lbs/yr. Across the 1634 electroplating and anodizing facilities in EPA's RTR database, this would result in a comprehensive national emissions estimate of 817 lbs/yr or 0.41 tons/yr. This more accurate estimate of total national emissions for the electroplating/anodizing source categories still represents only about 1% of EPA's (likely incomplete) NEI estimate of total national Cr(VI) emissions from all source categories.