

## Supplemental Materials

### Appendix 1: Health values and reference concentrations of hazardous air pollutants

#### Health values and reference concentrations of hazardous air pollutants

Hazardous Air Pollutant (HAP) Name	CAS No.	Non-Cancer		Cancer	
		Chronic RfC, REL or MRL in (µg/m <sup>3</sup> )	Source	URE (Unit Risk Estimate) in 1/(µg/m <sup>3</sup> )	Source
1,1,1,2-Tetrachloroethane	79-34-5			5.80E-05	IRIS & CAL
1,1,2-Trichloroethane	79-00-5	400.00	P-CAL (EPA OAQPS & NATA)	1.60E-05	IRIS & CAL
1,2,4-Trichlorobenzene	120-82-1	200.00	HEAST (NATA)		
1,2-Dibromo-3-chloropropane	96-12-8	0.20	IRIS	2.00E-03	CAL
1,2-Diphenylhydrazine	122-66-7			2.20E-04	IRIS
1,2-Epoxybutane	106-88-7	20.00	IRIS & CAL		
1,3-Butadiene	106-99-0	2.00	IRIS	1.70E-04	CAL
1,3-Dichloropropene	542-75-6	20.00	IRIS	4.00E-06	IRIS
1,3-Propane sultone	1120-71-4			6.90E-04	CAL
1,4-Dioxane	123-91-1	3000.00	CAL	7.70E-06	CAL
2,4,6-Trichlorophenol	88-06-2			2.00E-05	CAL
2,4-Dinitrotoluene	121-14-2	7.00	P-CAL(OAQPS & NATA)	8.90E-05	CAL
2,4-Toluene diamine	95-80-7			1.10E-03	CAL
2,4-Toluene diisocyanate	26471-62-5	0.07	IRIS & CAL	1.10E-05	CAL
2-Chloroacetophenone	532-27-4	0.03	IRIS		
2-Nitropropane <sup>c</sup>	79-46-9	20.00	IRIS	5.60E-06	OAQPS & NATA

3,3-Dichlorobenzidene	91-94-1			3.40E-04	CAL
3,3'-Dimethoxybenzidine	119-90-4			4.00E-06	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
3,3'-Dimethyl benzidine	119-93-7			2.60E-03	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
4,4'-Methylene bis(2-chloroaniline)	101-14-4			4.30E-04	CAL
4,4'-Methylenedianiline	101-77-9	20.00	CAL	4.60E-04	CAL
Acetaldehyde	75-07-0	9.00	IRIS & CAL	2.70E-06	CAL
Acetamide	60-35-5			2.00E-05	CAL
Acetonitrile	75-05-8	60.00	IRIS		
Acrolein	107-02-8	0.02	IRIS		
Acrylamide	79-06-1	0.70	P-CAL(OAQPS & NATA)	1.30E-03	IRIS & CAL
Acrylic acid	79-10-7	1.00	IRIS		
Acrylonitrile	107-13-1	2.00	IRIS	2.90E-04	CAL
Allyl chloride	107-05-1	1.00	IRIS	6.00E-06	CAL
Aniline	62-53-3	1.00	IRIS	1.60E-06	CAL
Antimony compounds	7440-36-0	0.20	IRIS(NATA)		
Arsenic compounds (inorganic, may include arsine)	7440-38-2	0.03	CAL	4.30E-03	IRIS
Arsine	7784-42-1	0.05	IRIS		
Asbestos	1332-21-4			6.30E-02	CAL
Benzene	71-43-2	30.00	IRIS	2.90E-05	CAL
Benzidine	92-87-5	10.00	P-CAL(OAQPS & NATA)	1.40E-01	CAL
Benzotrichloride	98-07-7			3.70E-03	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
Benzyl chloride	100-44-7			4.90E-05	IRIS & CAL

Beryllium compounds	7440-41-7	0.01	CAL	2.40E-03	IRIS & CAL
Bis(2-ethylhexyl)phthalate	117-81-7	10.00	P-CAL(OAQPS & NATA)	2.40E-06	CAL
Bis(chloromethyl)ether	542-88-1			6.20E-02	IRIS
Bromoform	75-25-2			1.10E-06	IRIS
Cadmium compounds	7440-43-9	0.02	CAL	4.20E-03	CAL
Captan	133-06-2			1.00E-06	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
Carbon disulfide	75-15-0	700.00	IRIS		
Carbon tetrachloride	56-23-5	40.00	CAL	4.20E-05	CAL
Chlordane	57-74-9	0.70	IRIS	1.00E-04	IRIS
Chlorine	7782-50-5	0.20	CAL		
Chlorobenzene	108-90-7	1000.00	CAL		
Chlorobenzilate	510-15-6			7.80E-05	HEAST (OAQPS & NATA)
Chloroform	67-66-3	98.00	ATSDR (OAQPS & NATA)	5.30E-06	CAL
Chloroprene	126-99-8	7.00	HEAST (NATA)		
Chromium VI <sup>d</sup>	18540-29-9	0.10	IRIS	1.50E-01	CAL
Cobalt compounds	7440-48-4	0.10	ATSDR (NATA)		
Coke Oven Emissions	8007-45-2			6.20E-04	IRIS
Cresols_Cresylic acid (isomers and mixture)	1319-77-3	600.00	CAL		
Cumene (Isopropyl benzene)	98-82-8	400.00	IRIS		
Cyanide compounds	57-12-5	3.00	IRIS(NATA)		
Dichloroethyl ether	111-44-4			7.10E-04	CAL
Dichlorvos	62-73-7	0.50	IRIS	8.30E-05	Conv.Oral <sup>ab</sup> (OAQPS & NATA)

Diesel exhaust	Diesel Emis	5.00	IRIS & CAL	3.00E-04	CAL
Diethanolamine	111-42-2	3.00	CAL		
Dimethyl formamide	68-12-2	30.00	IRIS		
Epichlorohydrin	106-89-8	1.00	IRIS	2.30E-05	CAL
Ethyl acrylate	140-88-5			1.40E-05	Conv.Oral <sup>lab</sup> (NATA)
Ethyl benzene	100-41-4	1000.00	IRIS		
Ethyl carbamate	51-79-6			2.90E-04	CAL
Ethyl chloride	75-00-3	10000.00	IRIS		
Ethylene dibromide	106-93-4	0.80	CAL	6.00E-04	IRIS
Ethylene dichloride	107-06-2	400.00	CAL	2.60E-05	IRIS
Ethylene glycol	107-21-1	400.00	CAL		
Ethylene oxide	75-21-8	30.00	CAL	8.80E-05	CAL
Ethylene thiourea	96-45-7	3.00	P-CAL(OAQPS & NATA)	1.30E-05	CAL
Ethylidene dichloride	75-34-3	500.00	HEAST (OAQPS & NATA)	1.60E-06	CAL
Formaldehyde <sup>e</sup>	50-00-0	3.00	CAL	6.00E-06	CAL
Glycol ethers <sup>f</sup>	7529-27-3	20.00	OAQPS(NATA)		
Heptachlor	76-44-8			1.30E-03	IRIS
Hexachlorobenzene	118-74-1	3.00	P-CAL(OAQPS & NATA)	5.10E-04	CAL
Hexachlorobutadiene	87-68-3	90.00	P-CAL(OAQPS & NATA)	2.20E-05	IRIS
Hexachlorocyclopentadiene	77-47-4	0.20	IRIS		
Hexachloroethane	67-72-1	80.00	P-CAL(OAQPS & NATA)	4.00E-06	IRIS
Hexamethylene-1,6-diisocyanate	822-06-0	0.01	IRIS		

Hexane	110-54-3	700.00	IRIS		
Hydrazine	302-01-2	0.20	CAL	4.90E-03	IRIS & CAL
Hydrochloric acid	7647-01-0	8.00	CAL		
Hydrofluoric acid	7664-39-3	14.00	CAL		
Isophorone	78-59-1	2000.00	CAL	2.70E-07	Conv.Oral <sup>bb</sup> (OAQPS & NATA)
Lead compounds	7439-92-1	1.50	OAQPS & NATA	1.20E-05	CAL
Lindane (all isomers)	58-89-9	0.30	PCAL (EPA OAQPS & NATA)	3.10E-04	CAL
Maleic anhydride	108-31-6	0.70	CAL		
Manganese compounds	7439-96-5	0.05	IRIS		
Mercury compounds	7439-97-6	0.09	CAL		
Methanol	67-56-1	4000.00	CAL		
Methyl bromide	74-83-9	5.00	IRIS & CAL		
Methyl chloride	74-87-3	90.00	IRIS		
Methyl chloroform	71-55-6	1000.00	CAL		
Methyl ethyl ketone <sup>g</sup>	78-93-3	5000.00	IRIS		
Methyl isobutyl ketone	108-10-1	3000.00	IRIS		
Methyl isocyanate	624-83-9	1.00	CAL		
Methyl methacrylate	80-62-6	700.00	IRIS		
Methyl tert butyl ether	1634-04-4	3000.00	IRIS	2.60E-07	CAL
Methylene chloride	75-09-2	400.00	CAL	1.00E-06	CAL
Methylene diphenyl diisocyanate	101-68-8	0.60	IRIS		
Naphthalene	91-20-3	3.00	IRIS	3.40E-05	CAL

Nickel compounds	7440-02-0	0.05	CAL	2.60E-04	CAL
Nitrobenzene	98-95-3	30.00	PCAL (EPA OAQPS & NATA)		
Nitrosodimethylamine	62-75-9			1.40E-02	IRIS
N-Nitrosomorpholine	59-89-2			1.90E-03	CAL
o-Toluidine <sup>h</sup>	95-53-4			5.10E-05	CAL (EPA OAQPS & NATA)
p-Dichlorobenzene	106-46-7	800.00	IRIS & CAL	1.10E-05	CAL
p-Dimethylaminoazobenzene	60-11-7			1.30E-03	CAL
Pentachloronitrobenzene	82-68-8			7.40E-05	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
Pentachlorophenol	87-86-5	100.00	PCAL (EPA OAQPS & NATA)		
Perchloroethylene	127-18-4	35.00	CAL	5.90E-06	CAL
Phenol	108-95-2	200.00	CAL		
Phosgene	75-44-5	0.30	IRIS		
Phosphine	7803-51-2	0.30	IRIS		
Phthalic anhydride	85-44-9	20.00	CAL		
Polychlorinated biphenyls (PCBs) <sup>i</sup>	1336-36-3			1.00E-04	IRIS & CAL
POM <sup>j</sup>					
POM Group 1: Unspeciated				5.50E-05	OAQPS (NATA) <sup>k</sup>
POM Group 2: no URE data				5.50E-05	OAQPS (NATA) <sup>k</sup>
POM Group 3: 5.0E-2<URE<=5.0E-1				1.00E-01	OAQPS (NATA) <sup>k</sup>
POM Group 4: 5.0E-3<URE<=5.0E-2				1.00E-02	OAQPS (NATA) <sup>k</sup>
POM Group 5: 5.0E-4<URE<=5.0E-3				1.00E-03	OAQPS (NATA) <sup>k</sup>
POM Group 6: 5.0E-5<URE<=5.0E-4				1.00E-04	OAQPS (NATA) <sup>k</sup>

POM Group 7: 5.0E-6<URE<=5.0E-5				1.00E-05	OAQPS (NATA) <sup>k</sup>
POM Group 8: Unspecified 7-PAH				2.00E-04	OAQPS (NATA) <sup>k</sup>
Propylene dichloride	78-87-5	4.00	IRIS	1.90E-05	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
Propylene oxide	75-56-9	30.00	IRIS & CAL	3.70E-06	IRIS & CAL
Quinoline	91-22-5			3.40E-03	Conv. Oral <sup>ab</sup> (NATA)
Selenium Compounds	7782-49-2	20.00	CAL		
Styrene	100-42-5	900.00	CAL		
Styrene oxide	96-09-3	6.00	PCAL (EPA OAQPS & NATA)		
Titanium tetrachloride	7550-45-0	0.10	ATSDR (NATA)		
Toluene	108-88-3	300.00	CAL		
Toxaphene	8001-35-2			3.20E-04	IRIS
Trichloroethylene	79-01-6	600.00	CAL	2.00E-06	CAL
Triethylamine	121-44-8	7.00	IRIS		
Trifluralin	1582-09-8			2.20E-06	Conv.Oral <sup>ab</sup> (OAQPS & NATA)
Vinyl acetate	108-05-4	200.00	IRIS & CAL		
Vinyl bromide	593-60-2	3.00	IRIS	3.20E-05	HEAST (OAQPS & NATA)
Vinyl chloride	75-01-4	100.00	IRIS	7.80E-05	CAL
Vinylidene chloride	75-35-4	70.00	CAL		
Xylenes (isomers and mixture)	1330-20-7	100.00	IRIS		

Abbreviations: CAL, California Office of Environmental Health Hazard Assessment (OEHHA); P-CAL, Pre-CAL, under consideration, but not yet adopted by California; IRIS, US EPA Integrated Risk Information System; IRIS & CAL, IRIS values which have been adopted by California OEHHA; OAQPS, Consolidated Health Risk Values Table from US EPA's Office of Air Quality Planning and Standards (OAQPS); NATA, Consolidated Health Risk Values Table from the US EPA's National Air Toxics Assessment; HEAST, US EPA Health Effects Assessment Tables (EPA PB97-921199); ATSDR, The Agency for Toxic Substances and Disease Registry; URE, unit risk estimate (URE is the upper-bound excess cancer risk

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estimated to result from a lifetime of continuous exposure to an agent, at a concentration of 1 µg/m<sup>3</sup>); CAS No., chemical abstracts services number for compound; RfC, reference concentration; REL, reference exposure level; MRL, minimal risk level.

<sup>a</sup>Conversion of carcinogenic oral potency (CPS) slope to inhalation unit risk estimate was based on the following assumptions: (1) whole-life, continuous exposure, (2) inhalation rate of 20 cubic meters of air per day, and (3) body mass of 70 kg; <sup>b</sup>Oral carcinogenic potency slope (CPS) factors and their respective source agencies used for conversions to an inhalation Unit Risk Estimate: Benzotrachloride, 1.30 E+1 (IRIS); Dichlorvos, 2.90 E-1 (IRIS); Isophorone, 9.50 E-4 (IRIS); Quinoline, 3.00 E+1 (IRIS); Trifluralin, 7.70 E-3 (IRIS); no sources found for Captan, 3,3-Demethoxybenzidine, 3,3-Dimethyl benzidine, Ethyl acrylate, Pentachloronitrobenzene or Propylene dichloride; <sup>c</sup>The assessment used a URE of 5.6E-6 (ug/m<sup>3</sup>)-1. This value was derived in 1999 by the Health Council of the Netherlands (available at <http://www.gr.nl/pdf.php?ID=423&p=1>) and is consistent with weight-of-evidence determinations by the U.S. National Toxicology Program (“reasonably anticipated to be a human carcinogen”) and IARC (“possibly carcinogenic to humans”); <sup>d</sup>The IRIS RfC for particulate hexavalent chromium was used in preference to the RfC for chromic acid mists and dissolved aerosols; <sup>e</sup>The EPA no longer considers the formaldehyde URE reported in IRIS, which is based on a 1987 study, to represent the best available science in the peer-reviewed literature. A new URE has been developed for formaldehyde which is based on a dose-response value developed by the CIIT Centers for Health Research (formerly the Chemical Industry Institute of Toxicology). At the time of manuscript preparation, this URE had not been fully peer reviewed, and it was the authors’ decision not to use this value. The new value was being used by EPA in their National Air Toxics Assessment. The unit risk estimate used in the article is from California OEHHA and is between the current IRIS peer reviewed value and the new value currently being evaluated by EPA. Therefore, this case is an exception to the rule that the authors established to use the most protective of the health risk values between California OEHHA and IRIS; <sup>f</sup> Most of the reporting information for glycol ether compounds reports only the total mass for the entire group and does not distinguish between individual glycol ether compounds. Long chain glycol ethers and ethylene glycol monobutyl ether were delisted as HAPs in 2000 and 2004, respectively. The RfC for ethylene glycol methyl ether (the most toxic for which an assessment exists) was applied in this assessment in order to avoid underestimating the health hazard associated with glycol ethers; <sup>g</sup>Methyl ethyl ketone was delisted as a HAP in 2005; <sup>h</sup>Reported as a California OEHHA value on OAQPS and NATA consolidated tables, but not found on California OEHHA tables, possibly an old value; <sup>i</sup>Low risk for use with unspecified PCB mixtures; <sup>j</sup>The EPA’s 1999 National Air Toxics Assessment divided POM emissions into eight categories. The first two categories were assigned a URE equal to 5% of that for pure benzo[a]pyrene. Categories 3-7 were composed of emissions that were reported as individual compounds. These compounds were placed in the category with an appropriate URE. Category 8, composed of unspecified carcinogenic polynuclear aromatic hydrocarbons (a subset of POM called 7-PAH), was assigned a URE equal to 18% of that for pure benzo[a]pyrene; <sup>k</sup>Value derived by OAQPS for use in NATA evaluation of Polycyclic Organic Matter (POM).

## **Appendix 2: The Risk Ranking Procedure Illustrated for Benzene**

Consider the key question addressed in this risk ranking procedure: “Which ambient air pollutants are the most likely to pose significant health risks for current and future residents of Houston?” For purposes of this report, ambient air pollutants include: HAPs and diesel particulates, as well as two criteria pollutants, ozone and fine particulates. The task was to assign priority among these contaminants based on the relative health risk that each poses to the residents of the Greater Houston area. Although a full quantitative risk assessment was not possible, we were able to screen the pollutants by comparing estimates of their ambient concentrations against authoritative health risk values for cancer and reference values for chronic disease, whenever these were available. Health risk values were calculated from inhalation, unit risk estimates. The reference values were based on inhalation, reference concentrations; while not a direct estimate of risk, these specify levels at or below which adverse health effects are not likely to occur. As a rule, we relied on current, EPA-sanctioned (final, peer-reviewed) values and concentrations, unless more stringent levels had been promulgated by California EPA. Estimates of ambient concentrations were drawn from two, independent sources: the NATA modeled averages for 1999 (available in Spring of 2006) (U.S. EPA 2006a) and the monitoring averages for 2004 drawn from EPA’s Air Quality System (U.S. EPA 2006b).

Since our purpose is to establish an ordering among pollutants in terms of relative risks, we created 4 ranked categories – unlikely, possible, probable and definite -- each designating a particular level of risk. A fifth category, uncertain, was added to cover instances when ambiguity or a lack of information kept us from determining an

appropriate risk level. Using categories permits us to accommodate a range of numerical values at each risk level and to allow for imprecision in our estimates. We are also able to take advantage of some widely-used qualitative distinctions among risk levels, making the categories more meaningful.

The assignment of pollutants to these 5 risk categories works in three rounds. In the first and longest round, data on the ambient concentration of each pollutant are collected from NATA's modeled estimate for each census tract and from the measured estimates from AQS monitors. These data are then screened relative to selected threshold levels for each unit risk estimate and reference concentration corresponding to the pollutant under consideration.

There were 4 threshold concentrations computed from each available unit risk estimate; these formed the boundaries of 5 risk groupings, each corresponding to added lifetime cancer risk to the population – “Below 1/1,000,000” “Between 1/100,000 and 1/1,000,000” “Between 1/10,000 and 1/100,000” “Between 1/1,000 and 1/10,000” “1/1,000 and Greater”. Similarly, there were 3 percentile thresholds computed for each reference concentration, also leading to 5 groupings – “Below 50% RfC” “Between 75% and 50% RfC” “Between 100% and 75% RfC” “Between 150% and 100% RfC” and “150% and Above”.

Pollutants are then assigned to the appropriate grouping based on their modeled NATA concentrations and their measured AQS concentrations, taken separately. As a result, there are four distinctive orderings: a unit risk estimate grouping for NATA concentrations and one for AQS concentrations, together with a reference concentration grouping for each. Within each of these groupings, pollutants are sorted first by their

relative emissions masses reported in the National Emissions Inventory (NEI) for 1999 (U.S. EPA 2006c). Four percentile categories were used: “90<sup>th</sup> Percentile and Above” “89<sup>th</sup> to 75<sup>th</sup> Percentile” “74<sup>th</sup> to 50<sup>th</sup> Percentile” and “Below 50<sup>th</sup> Percentile”. Within each of these categories, pollutants are then sorted by the number of census tracts or monitors yielding concentrations above the threshold risk or reference levels for that grouping; this provides a rough indication of the relative extent of exposure in the population. The mass and location factors become important in the third round. Those pollutants with neither a unit risk estimate nor a reference concentration are assigned to a residual group, as are those with either no concentrations reported or modeled concentrations of zero.

In the second round, we apply a decision rule to take us from the 4 elaborate orderings developed in the first round to our 5 overall risk categories. In effect, the rule assigns each grouping to a particular risk category and, thereby, creates a default assignment for each pollutant. Pollutants with concentrations that place them in the two highest groupings – “Between 1/1,000 and 1/10,000” and “1/1,000 or Greater” for unit risk thresholds and “Between 150% RfC and 100% RfC” and “150% RfC and Above” for reference thresholds -- go to the “Definite Risk” category. Those in the next highest grouping go to Probable Risk; and those in the grouping below that one go to Possible Risk. Those in the lowest grouping – “Below 1/1,000,000” and “Below 50% RfC” – are assigned to the Uncertain category, along with the pollutants in the residual group without unit risk estimates or reference concentrations. Pollutants with evidence of no emissions in the Greater Houston Area, modeled concentrations of zero, or no measured concentrations reported, go to the Unlikely category. Note that both AQS

and NATA concentrations are combined in the same categories at this point. Although preference is given to the measured over the modeled data, only just over 20 pollutants with a health or reference value have both kinds of data. Although these pollutants may appear in multiple categories as a result, in every case, we assign them to the highest category in which they appear.

In the third round, adjustments are made to improve the reliability of the default assignments. Here, the emissions and location factors come into play. If there is evidence that emissions levels have changed dramatically, the pollutant can be moved to a lower risk category (1 pollutant). Pollutants whose assignments are based on a modeled concentration in only a single census tract can be moved to a lower risk category (7 pollutants). Those whose health or reference values are based on oral rather than inhalation evidence can be moved to a lower category (3 pollutants). A total of 11 pollutants were moved in this round to produce the final assignments to our 5 risk categories.

To illustrate this process, consider the pollutant, benzene; it has both a unit risk estimate and a reference concentration and appears in both modeled and measured concentration estimates. Using the Cal/EPA unit risk estimate for benzene,  $2.9 \times 10^{-5}$  per  $\mu\text{g}/\text{m}^3$ , we calculate the threshold risk concentrations as follows. Take a particular, lifetime, cancer risk level, say, 1 in 10,000 expressed as  $1/10,000$ , and then divide it by the unit risk estimate. This means that the air concentration at each of these threshold levels changes by a factor of 10, the same as the change in the risk levels ( $1/10,000$ :  $3.4 \mu\text{g}/\text{m}^3$ ;  $1/100,000$ :  $3.4 \times 10^{-1} \mu\text{g}/\text{m}^3$ ;  $1/1,000,000$ :  $3.4 \times 10^{-2} \mu\text{g}/\text{m}^3$ ). The highest modeled concentration for benzene from NATA is 9.04; the concentrations for

66 census tracts exceed 3.4, our threshold for the “Between 1/1,000 and 1/10,000” cancer risk grouping. The highest measured concentration is 5.51. Two monitors show annual averages exceeding 3.4 ug/m<sup>3</sup>. This places benzene in the same grouping for both measured and modeled concentrations. The reference value thresholds are based on percentages of the reference concentration, ranging from 150% to below 50%. For benzene, the reference value is 30 ug/m<sup>3</sup>. Again, measured and modeled concentrations lead to the same grouping, “Below 50% RfC”.

In the second round, benzene is assigned to the Definite Risk category, since the top two risk groupings have been combined. Its lowest grouping on the reference concentration does not affect this assignment. Finally, in the third round, benzene’s emissions mass above the 90<sup>th</sup> percentile and its appearance above threshold levels in 66 census tracts and at two monitors reinforce the default assignment.

## References

U.S. EPA (U.S. Environmental Protection Agency). 2006a. 1999 National-scale Air Toxics Assessment: 1999 Data Tables. Texas State Summary Database.

ASPEN. Available: <http://www.epa.gov/ttn/atw/nata1999/tables.html> [accessed 27 February 2006].

U.S. EPA (U.S. Environmental Protection Agency). 2006b. Air Quality System. Data on Hazardous Air Pollutants and Criteria Pollutants. Available:

<http://www.epa.gov/ttn/airs/airsaqs/index.htm> [accessed 20 March 2006].

U.S. EPA (U.S. Environmental Protection Agency). 2006c. 1999 National-scale Air Toxics Assessment: 1999 Data Tables. Texas State Summary Database (NEI)

and County-level Emission Summaries. Available:

<http://www.epa.gov/ttn/atw/nata1999/tables.html> [accessed 11 March 2006].

### **Appendix 3: Chromium and Diesel PM Conversions**

The U.S. EPA's 1999 National Air Toxics Assessment (NATA) (U.S. EPA 2006a) modeling and analyses used fine and coarse PM data in modeling metal concentrations. The Mayor's Task Force analyses used only fine PM metal concentrations from PM 2.5 speciated metals data files from the U.S. EPA's Air Quality System database (U.S. EPA 2006b) to compare to reference concentrations (RfCs) and unit risk estimates (UREs). The choice to eliminate the PM 10 speciated metals data was based on the assumption that PM 2.5 particles would penetrate further into the lungs and therefore represent greater health consequences than PM 10 speciated metals. After completing the analyses, it was found that metal concentrations from ambient PM 2.5 speciated metals files for 2004 were consistently lower than the modeled NATA concentrations from 1999. The inconsistency between the modeled and ambient data analyses is further complicated by the fact that the time frame for these analyses is separated by five years. The NATA Model-to-Monitor Comparison (U.S. EPA 2007) reported that measured ambient metal concentrations were typically higher than modeled concentrations for chromium, lead, manganese and nickel. Recalculating our ambient metal concentrations to include both fine and coarse speciated metals may lead to higher risk categories reported for metals from ambient datasets.

#### **Chromium Compounds**

Chromium compounds, which are a group of pollutants, are listed in the Clean Air Act as one of the 188 Hazardous Air Pollutants (HAPs). Chromium sources of emissions include the combustion of coal and oil, electroplating, vehicles, iron and steel plants, and metal smelters. Chromium occurs in the environment primarily in two

valence states, trivalent chromium (Cr III), which occurs naturally and is an essential nutrient, and hexavalent chromium (Cr VI), which along with the less common metallic chromium (Cr 0), is most commonly produced by industrial processes. Air emissions of chromium are predominantly of trivalent chromium, and in the form of small particles or aerosols. Chromium forms a large number of compounds, in both the chromium (III) and chromium (VI) forms (ATSDR 1998). The Mayor's Task Force assessed chromium (VI) compounds as a group of pollutants using modeled concentrations from the U.S. Environmental Protection Agency's 1999 National Air Toxics Assessment (U.S. EPA 2006c). Modeled chromium VI compound concentrations were assessed for carcinogenic and non-carcinogenic endpoints. Currently, no UREs or RfCs exist from the sources consulted for chromium III compounds and chromium III is much less toxic than chromium VI.

The emissions of chromium compounds reflected in the 1999 NATA assessment are based on state and local agency reporting of chromium as "chromium and compounds," individual chromium compounds and chromium ions. In the EPA's 1996 National Air Toxics Assessment (U.S. EPA 1999), because of the inconsistent reporting, all of the chromium was lumped together for dispersion modeling as "Chromium VI." EPA then based quantitative risk estimates on an assumption that 34 percent of the chromium is hexavalent chromium based on information from past inventorying efforts. For 1999, EPA used a more refined approach to estimate emissions of hexavalent chromium. Individual compounds of chromium reported in the inventory were identified as either hexavalent or trivalent based upon their chemical formulae. Any compounds reported as either "chromium" or "chromium and compounds" were then speciated

using source category specific speciation data (U.S. EPA 2004). For source categories where speciation data were not available, EPA assumed that 34 percent of the chromium is hexavalent.

### **Elemental Carbon to Diesel PM Conversion Factor**

In order to assess diesel particulate matter concentrations the Task Force used ambient elemental carbon (EC) carbon concentrations for 2004 (U.S. EPA 2006d) as a surrogate for diesel particulate matter (PM) concentrations. This technique used the relative contributions of diesel combustion other sources to ambient EC contributions to determine a scaling factor to related EC to diesel PM concentrations. Sources of EC in the Houston area include gas and diesel vehicles, road dust, vegetative detritus, wood combustion, meat cooking and fuel oil combustion. A study by Fraser, et al. (Fraser et al. 2003) used organic molecular markers specific to the above sources to apportion fine particulate matter at four sites in Houston, Texas. The samples used in this study were collected between March 1997 and February 1998. Two sites from this study, Clinton (adjacent to the Houston Ship Channel in the vicinity of a high concentration of industrial emission sources) and Bingle (located in a suburban neighborhood in north-west Houston) were used to develop an appropriate scaling factor to relate ambient EC levels to diesel PM concentrations. Raw data from this study was obtained from Fraser and the ratio of elemental carbon attributed to diesel exhaust to total apportioned elemental carbon at each site was determined to be 0.775 at Clinton and 0.887 at Bingle.

In a second study by Fraser, et al. (Fraser et al. 2002) samples of fine particle emissions from four heavy-duty diesel vehicles were analyzed for chemical and

molecular composition. Particle emissions were sampled for vehicles under load and idling. Ratios of elemental carbon to total carbon (EC/TC) for diesel emissions from two tractor-trailer trucks from the fleet of the HEB Grocery Company of San Antonio, Texas running at an Heavy-Duty Chassis Cycle (HDCC), designed to simulate urban and highway operation, were measure in a range of 0.66 – 0.72. The mean and median of this range is 0.69.

In order to calculate conversion factors for ambient measured EC to diesel (PM) concentrations, the data mentioned from the two studies by Fraser et al. were used. Factors for conversion were calculated for both the Clinton and Bingle sites by dividing the ratio of fine elemental carbon mass attributed to diesel PM in the Houston atmosphere at each site (0.775 at Clinton and 0.887 at Bingle) by the EC/TC ratio of 0.69 for diesel engine emissions from the two representative tractor-trailer trucks. This calculation assumes that these two diesel trucks provide an accurate representation of the diesel vehicle fleet as a whole in Houston. This assumption was required because source apportionment of elemental carbon to diesel sources other than diesel truck engines at our monitoring sites in the Houston area was not directly available.

Our conversion factors were calculated as follows:

*Clinton:*

$$(0.775)/(0.69) = 1.12$$

*Bingle:*

$$(0.887)/(0.69) = 1.29$$

Estimates of ambient diesel PM concentrations can then be made by multiplying the elemental carbon concentrations measured at a local air quality monitoring location by one of the conversion factors above.

Several other conversion factors used by the California Air Resources Board (ARB) (Cal ARB and OEHHA 1998; Cal ARB 1998) in their identification of particulate emissions from diesel fueled engines as a toxic air contaminant and by the U.S. EPA (U.S. EPA 2002) were also found. The ARB used a study by Gray (Gray 1986) which showed that the ratio of fine elemental carbon mass attributed to diesel engine emissions to total elemental carbon in the Los Angeles atmosphere was approximately 0.67. The EC/TC ratio for all diesel exhaust particles emitted was 0.64. Therefore, diesel particulate concentrations are estimated by multiplying the elemental carbon concentrations by 1.04 ( $0.67/0.64 = 1.04$ ).

The U.S. EPA also calculated elemental carbon to diesel PM conversion factors for various areas in the United States using seven different studies (U.S. EPA 2002), as well as raw data obtained from various researchers involved in the studies. For the Western United States, which encompasses the state of Texas, an average EC to diesel PM conversion factor of 1.6 was calculated for elemental carbon measurements using the thermal optical transmittance (TOT) method and an average value of 0.8 was calculated for elemental carbon measurements using the thermal optical reflectance (TOR) measurement method during winter months in the Eastern and Western United States.

#### **Elemental Carbon to Diesel Particulate Matter Conversions**

<b>Study</b>	<b>Conversion Factor</b>
Fraser – Clinton	1.12
Fraser – Bingle	1.29
Cal. Air Resources Board	1.04
EPA – TOT Method	1.60

EPA – TOR Method                      0.80

The conversion factor chosen to be used in this analysis was 1.12 calculated from the local Houston data obtained by Fraser et al. (Fraser et al. 2002; 2003). This value was within the range of the other values that were calculated from various sources (1.04 – 1.60) and was chosen because it was calculated using data representing the Houston area at a monitoring site located within the East Houston area.

The ambient monitoring data obtained from EPA had various measurements for elemental carbon making it necessary to determine which monitors were appropriate for our analyses. Under advice from staff at the U.S. Environmental Protection Agency, parameter code 88307 – Elemental Carbon Stn PM 2.5 and parameter code 88321 – EC Improve PM 2.5 LC (U.S. EPA 2006d) were used for analyses. These two data types represent different monitoring procedures and different monitoring locations, but can both act as a surrogate for diesel PM conversions. Parameter code 88307 – Elemental Carbon Stn PM 2.5 monitoring sites are in urban areas and use the Thermal Optical Transmittance (TOT) method. Parameter code 88321 – EC Improve PM 2.5 LC monitoring sites are in rural areas and use the Thermal Optical Reflectance (TOR) method. It was decided to use both types of measurements in our analyses.

Concentrations of elemental carbon from the following Houston monitoring sites were used in our analyses:

<b>Site Name</b>	<b>Parameter Code</b>
Galveston Airport	88307
Houston Aldine	88307

Channelview	88307
Houston Bayland Park	88307
Houston East	88307
Houston Deer Park 2	88307
Houston Deer Park 2	88321
Conroe (Relocated)	88307

Cancer evaluations of diesel emissions vary between the U.S. Environmental Protection Agency (U.S. EPA) and the California Office of Environmental Health Hazard Assessment (OEHHA). The U.S. EPA has determined that diesel exhaust is likely to be carcinogenic to humans but has judged that toxicological data are not yet sufficient to develop a unit risk estimate for cancer evaluations. The California (OEHHA) Diesel Exhaust Toxic Air Contaminant (TAC) document (Cal ARB and OEHHA 1998) stated that the results of epidemiological analyses are consistent with a positive association between occupational exposure to diesel exhaust and an increased risk of developing lung cancer and has developed a cancer unit risk estimate (URE) for diesel exhaust. The Mayor's Task Force analysis has used the URE developed by OEHHA for the cancer assessment for diesel exhaust. Diesel emissions have been assessed for effects other than cancer by the U.S. EPA's Integrated Risk Information System (IRIS) program and this Reference Concentration (RfC) value has also been adopted by the OEHHA.

It should be noted that in the evaluation done by the Mayor's Task Force the cancer unit risk estimate that was used from the California OEHHA was for diesel exhaust which includes both particulate and vapor phases. This number was applied to

the diesel particulate matter concentrations estimated by the NATA, which does not include the vapor phase chemicals.

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**Appendix 4: Health effects and emission source of pollutants included in “Uncertain risks” category**

Health effects and emission source of pollutants included in “Uncertain risks” category, Greater Houston<sup>a</sup>, 1999

Air Pollutant	Health Effects <sup>b</sup>		Emission Source <sup>c</sup>		
	Cancer endpoint	Chronic endpoint	Point	Mobile	
				On Road	Off Road
1,2-Dichloropropane (propylene dichloride)	Yes	Respiratory	X		X
Ethyl Acrylate	Yes		X		X
Quinoline	Yes				X
Aniline	Yes	Spleen	X		X
Hexachloroethane	Yes	Kidney	X		X
Isophorone	Yes	Development	X		X
2,4-Toluene Diisocyanate	Yes	Respiratory	X		X
2-Nitropropane	Yes	Alimentary (liver)			X
3,3-Dichlorobenzidene	Yes		X		X
4,4'-Methylene bis(2-Chloroaniline)	Yes				X
4,4'-Methylenedianiline	Yes	Eyes	X		X
Acetamide	Yes		X		X
Allyl Chloride	Yes	Nervous	X		X
Asbestos	Yes				X
Benzotrichloride	Yes				X
Benzyl Chloride	Yes				X
Beryllium Compounds	Yes	Respiratory	X	X	X
Bis(Chloromethyl) Ether	Yes				X
Bromoform	Yes		X		X
Captan	Yes				X

Chlordane	Yes	Alimentary (liver)					X
Dichlorvos	Yes	Nervous					X
Heptachlor	Yes						X
Hexachlorobenzene	Yes	Alimentary (liver)	X				X
Hexachlorobutadiene	Yes	Reproductive	X				X
o-Toluidine	Yes		X				X
Pentachloronitrobenzene (Quintobenzene)	Yes						X
Pentachlorophenol	Yes	Alimentary (liver)					X
Trifluralin	Yes						X
Vinyl Bromide	Yes	Alimentary (liver)					X
Ethylbenzene		Development	X	X	X		X
Hexane (N-Hexane)		Nervous	X	X	X		X
Methyl Chloroform (1,1,1- Trichloroethane)		Nervous	X				X
Methyl Ethyl Ketone (2-Butanone)		Development	X				X
Styrene		Nervous	X	X	X		X
Toluene		Nervous (some)	X	X	X		X
Acetonitrile		Mortality (whole body)	X				X
Chlorobenzene		Alimentary (liver), Kidney, Male Reproductive System	X				X
Cyanide Compounds		Nervous	X				X
Methyl Bromide (Bromomethane)		Respiratory	X				X
Methyl Chloride (Chloromethane)		Nervous	X				X
Methyl Isobutyl Ketone (Hexone)		Development	X				X
Vinyl Acetate		Respiratory	X				X
1,2,4-Trichlorobenzene		Alimentary (liver)	X				X
Antimony Compounds		Respiratory	X				X

Maleic Anhydride		Respiratory	X			X
Methyl Methacrylate		Respiratory	X			X
Selenium Compounds		Alimentary (liver), Haematological, Nervous	X		X	X
Vinylidene Chloride (1,1-Dichloroethylene)		Alimentary (liver), Kidney	X			X
1,2-Epoxybutane		Respiratory	X			X
4,4'-Methylenediphenyl Diisocyanate (MDI)		Respiratory	X			X
Chloroprene		Respiratory	X			X
Ethylidene Dichloride (1,1-Dichloroethane)	Yes	Kidney	X			
Hexachlorocyclopentadiene		Respiratory	X			X
Hydrazine	Yes	Alimentary (liver), Endocrine	X			X
Mercury Compounds		Nervous	X			X
Methyl Isocyanate		Respiratory; Decreased weight gain	X			X
Phosphine		Whole body (decreased weight)				X
Styrene Oxide		Respiratory	X			X
Triethylamine		Respiratory	X			X
Isopropylbenzene (Cumene)		Kidney and Endocrine	X	X	X	X
2,2,4-Trimethylpentane			X	X	X	X
Polychlorinated Biphenyls (Aroclors)	Yes		X			X
1,2-Diphenylhydrazine	Yes					
Propoxur						
Hydrochloric Acid (Hydrogen		Respiratory	X			X

Chloride [Gas Only])					
Methanol	Development	X			X
Xylenes (Mixed Isomers)	Nervous	X	X	X	X
Carbonyl Sulfide		X			X
Cresol/Cresylic Acid (Mixed Isomers)	Nervous	X			X
Ethylene Glycol	Respiratory	X			X
Glycol Ethers	Reproductive	X			X
Hydrogen Fluoride (Hydrofluoric Acid)	Skeletal flurosis (increased bone density)	X			X
Propionaldehyde		X	X	X	X
Acetophenone		X			X
Biphenyl		X			X
Carbon Disulfide	Nervous	X			X
Diethanolamine	Respiratory	X			X
Diethyl Sulfate		X		X	X
Ethyl Chloride	Development	X			X
Methyl Iodide (Iodomethane)		X			X
Dimethylformamide	Alimentary (liver)	X	X	X	X
Phenol	Include Liver & Nervous	X			X
Phthalic Anhydride	Respiratory, Eyes	X			X
1,1-Dimethylhydrazine					X
1,2-Propylenimine (2-Methylaziridine)					X
2,4-Dichlorophenoxyacetic Acid (Including Salts and Esters)					X
4,6-Dinitro-o-Cresol (Including Salts)		X			X

4-Nitrophenol			X
Carbaryl			X
Catechol			X
Chloroacetic Acid			X
Chloromethyl Methyl Ether			X
Cobalt Compounds	Respiratory	X	X
Dibenzofuran			X
Dibutyl Phthalate		X	X
Dimethyl Phthalate		X	X
Dimethyl Sulfate			X
Ethyleneimine (Aziridine)		X	
Fine Mineral Fibers			X
Hydroquinone		X	X
Methylhydrazine			X
Nitrobenzene	Respiratory	X	X
o-Anisidine			X
Phosgene	Respiratory	X	X
p-Phenylenediamine			X
Quinone (p-Benzoquinone)		X	X
2-Acetylaminofluorene			
4-Aminobiphenyl			
4-Nitrobiphenyl			
Beta-Propiolactone			
Calcium cyanamide			
Diazomethane			
Dimethyl carbamoyl chloride			
Hexamethylphosphoramide			

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Methoxychlor

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N-Nitroso-N-methylurea

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Parathion

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<sup>a</sup> Greater Houston consists of the 10 county, Houston-Sugar Land-Baytown metropolitan statistical area (MSA) defined by the U.S. Census Bureau as of 2003. <sup>b</sup> Only chronic health effects associated with the chronic health value used in the analysis are depicted in the table. <sup>c</sup> U.S. EPA. 2006. 1999 National-scale Air Toxics Assessment: 1999 Data Tables. Texas State Summary Database and County-level Emission Summaries. Available: <http://www.epa.gov/ttn/atw/nata1999/tables.html> [accessed 11 March 2006].