



Development Support Document
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Chromic Acid Mist

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(Based on Hexavalent Chromium Content)

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Acronyms and Abbreviations

Acronyms and Abbreviations	Definition
ATSDR	Agency for Toxic Substances and Disease Registry
AMCV	Air monitoring comparison values
CalEPA	California Environmental Protection Agency
CrVI	hexavalent chromium
d	day
DSD	development support document
ESL	Effects Screening Level
^{acute} ESL	acute health-based Effects Screening Level for chemicals meeting minimum database requirements
^{acute} ESL _{odor}	acute odor-based Effects Screening Level
^{acute} ESL _{veg}	acute vegetation-based Effects Screening Level
^{chronic} ESL _{nonthreshold(c)}	chronic health-based Effects Screening Level for nonthreshold (i.e., linear) dose-response cancer effect
^{chronic} ESL _{threshold(nc)}	chronic health-based Effects Screening Level for threshold dose-response noncancer effects
^{chronic} ESL _{veg}	chronic vegetation-based Effects Screening Level
h	hour
HEC	human equivalent concentration
HQ	hazard quotient
LOAEL	lowest-observed-adverse-effect-level
MW	molecular weight
μg	microgram
Mm	millimeter
MOA	mode of action
MRL	Minimal Risk Level
NOAEL	no-observed-adverse-effect-level
NTP	National Toxicology Program
POD	point of departure
POD _{HEC}	point of departure adjusted for human equivalent concentration
POD _{OC}	point of departure for occupational exposure
ReV	Reference Value
RfC	Reference Concentration
TCEQ	Texas Commission on Environmental Quality
TD	Toxicology Division
UF	uncertainty factor
UF _H	interindividual or intraspecies human uncertainty factor
UF _{Sub}	subchronic to chronic exposure uncertainty factor
UF _L	LOAEL to NOAEL uncertainty factor
UF _D	incomplete database uncertainty factor

Acronyms and Abbreviations	Definition
URF	unit risk factor
USEPA	United States Environmental Protection Agency
VE _{ho}	default occupational ventilation rate for an eight-hour d
VE _h	default non-occupational ventilation rate for a 24-h d
week _{oc}	occupational weekly exposure frequency (study specific)
week _{res}	residential weekly exposure frequency (7 days per week)
WOE	weight of evidence

Chapter 1 Summary Tables

Table 1 for air monitoring and Table 2 for air permitting provide a summary of health- and welfare-based values from the acute and chronic evaluations of chromic acid mist, which contains hexavalent chromium (CrVI). Please refer to Section 1.6.2 of the TCEQ Guidelines to Develop Toxicity Factors (TCEQ 2012) for an explanation of air monitoring comparison values (AMCVs), reference values (ReVs), and effects screening levels (ESLs) used for review of ambient air monitoring data and air permitting. Table 3 contains chemical and physical properties of chromic acid (ATSDR 2008).

Table 1. Air Monitoring Comparison Values (AMCVs) for Ambient Air^a

Short-Term Values^b	Concentration	Notes
Acute ReV [24-h] (HQ = 1.0)	Short-Term Health 0.10 µg CrVI/m ³ Based on CrVI content in Chromic Acid Mist	Critical Effect(s): Upper respiratory tract effects (e.g., nasal symptoms/irritation) in workers
^{acute} ESL _{odor}	- - -	Insufficient Data
^{acute} ESL _{veg}	- - -	Insufficient Data
Long-Term Values^b	Concentration	Notes
Chronic ReV (HQ = 1.0)	0.012 µg CrVI/m ³ Based on CrVI content in Chromic Acid Mist	Critical Effect(s): Upper respiratory tract effects (e.g., nasal symptoms/irritation) in workers
^{chronic} ESL _{nonthreshold(c)}	Long-Term Health 0.0043 µg CrVI/m ^{3 c} as CrVI	Critical Effect(s): Lung cancer in industrial workers
^{chronic} ESL _{veg}	- - -	Insufficient Data

^a Chromic acid mist is not specifically monitored for by the TCEQ's ambient air monitoring program, so currently no ambient air data are available to assess concentrations in Texas ambient air.

^b Chromium compounds are respiratory sensitizers.

^c Based on an inhalation unit risk factor (URF) of 2.3×10^{-3} per µg CrVI/m³ and a no significant risk level of 1 in 100,000 excess cancer risk as derived in the hexavalent chromium and compounds DSD (TCEQ 2014), and applicable to CrVI in all forms of CrVI compounds (e.g., particulate, chromic acid).

Table 2. Air Permitting Effects Screening Levels (ESLs)

Short-Term Values ^a	Concentration	Notes
^{acute} ESL [24-h] (HQ = 0.3)	0.030 µg CrVI/m ³ ^b Based on CrVI content in Chromic Acid Mist Short-Term ESL for Air Permit Reviews	Critical Effect(s): Upper respiratory tract effects (e.g., nasal symptoms/ irritation) in workers
^{acute} ESL _{odor}	- - -	Insufficient Data
^{acute} ESL _{veg}	- - -	Insufficient Data
Long-Term Values ^a	Concentration	Notes
^{chronic} ESL _{threshold(nc)} (HQ = 0.3)	0.0036 µg CrVI/m ³ ^c Based on CrVI content in Chromic Acid Mist Long-Term ESL for Air Permit Reviews	Critical Effect(s): Upper respiratory tract effects (e.g., nasal symptoms/ irritation) in workers
^{chronic} ESL _{nonthreshold(c)}	0.0043 µg CrVI/m ³ ^d as CrVI	Critical Effect(s): Lung cancer in industrial workers
^{chronic} ESL _{veg}	- - -	Insufficient Data


^a In general, to protect against sensitization, exceedances of the acute (or chronic) ESL during the air permit review should be discouraged for any chemicals identified as respiratory sensitizers.

^b Based on the chromic acid mist acute ReV of 0.10 µg/m³ multiplied by 0.3 to account for cumulative and aggregate risk during the air permit review.

^c Based on the chromic acid mist chronic ReV of 0.012 µg/m³ multiplied by 0.3 to account for cumulative and aggregate risk during the air permit review.

^d Based on an inhalation unit risk factor (URF) of 2.3×10^{-3} per µg CrVI/m³ and a no significant risk level of 1 in 100,000 excess cancer risk as derived in the hexavalent chromium and compounds DSD (TCEQ 2014), and applicable to CrVI in all forms of CrVI compounds (e.g., particulate, chromic acid mist).

Table 3. Chemical and Physical Properties of Chromic Acid

Parameter	Value ^a	Reference
Name of Chemical	Chromic acid	ATSDR (2008)
Molecular Formula	H ₂ CrO ₄	ATSDR (2008)
Chemical Structure		ATSDR (2008)
Molecular Weight	118	ATSDR (2008)
Physical State	Solid	ATSDR (2008)
Color	Dark purple-red	ATSDR (2008)
Odor	No data	ATSDR (2008)
CAS Registry Number	7738-94-5	ATSDR (2008)
Synonyms	Chromic acid, Acide chromique	ATSDR (2008)
Solubility in water (mg/L)	1,000,000 at 17°C	ATSDR (2008)
Log K _{ow}	Not applicable	ATSDR (2008)
Vapor Pressure (mm Hg)	No data	ATSDR (2008)
Density (g/cm ³)	2.245 at 20°C	ATSDR (2008)
Melting Point	196°C	ATSDR (2008)
Boiling Point	Decomposes before boiling	ATSDR (2008)

^a Parameter values are not for aqueous chromic acid mist and would vary with composition (e.g., percent chromium trioxide).

Chapter 2 Major Uses, Sources, and Exposure Potential

2.1 Major Uses and Sources

The United States is a major importer of chromium (hundreds of thousands of metric tons per year) and a major producer of the end products of chromium for various uses (ATSDR 2008). CrVI compounds are widely used in metal finishing and chrome plating, in stainless steel production, in leather tanning, in wood preservatives, in the manufacture of pigments, and as corrosion inhibitors (NTP 2011).

The primary natural source of chromium in the atmosphere is continental dust flux; volcanic dust and gas flux are minor natural sources of chromium in the atmosphere. The major sources of atmospheric chromium, however, are particulate releases from stationary point sources such as industrial, commercial, and residential fuel combustion, and via the combustion of natural gas, oil, and coal. Other potential sources include cement-producing plants, the incineration of municipal refuse and sewage sludge, and emissions from chromium-based automotive catalytic converters (ATSDR 2008). See the hexavalent chromium and compounds development support document (DSD) for CrVI particulates for more extensive information on the uses and sources of CrVI compounds as a group (TCEQ 2014).

More specifically, chromic acid (H_2CrO_4 ; commonly manufactured by dissolving chromium trioxide in an aqueous solution) is used to electroplate chromium onto metal parts to provide a decorative or protective coating. A wide range of metals and plastics are electro-plated to produce a durable, tarnish resistant, and high luster “chrome” finish. Uses include domestic appliances, plumbing fixtures, automobile accessories, and even hospital equipment where it provides hygienic, easy-to-clean surfaces. Functional chrome plating, often referred to as hard chrome plating, involves applying much thicker layers for heavy industrial applications. Hard chrome has exceptional wear and corrosion resistance and is typically used in metal working machinery, engine cylinders, cutting tools, and hydraulic ram coatings. Chromic acid is also used extensively as an ingredient in formulating industrial wood preservatives. As a wood preservative, it acts as a fixative to bind biocides to the wood to provide protection against insect and fungal attack (Elementis 2014).

2.2 Exposure Potential

Chromic acid is produced by adding a soluble CrVI compound (e.g., chromium trioxide) to an aqueous solution to yield H_2CrO_4 . Chromium trioxide (CrO_3), in varying percentages by weight, is commonly used to produce chromic acid. This chromic acid solution has the potential to be emitted as an aqueous mist from chrome-plating processes. However, while occupational exposure may be likely (e.g., electroplating workers), the general public has a limited potential for exposure to chromic acid mist. That is, the most likely environmental CrVI exposures are to particulate CrVI compounds (ATSDR 2012).

Chapter 3 Acute Evaluation

3.1 Health-Based Acute ReV and ESL

Although an acute ReV is usually derived based on a 1-hour (h) exposure duration, studies evaluating adverse effects due to such short-term exposure to CrVI are very limited (e.g., LC₅₀ data). The studies available in the scientific peer-reviewed literature from which to identify an appropriate point of departure (POD) for derivation of a short-term, health-protective air concentration for chromic acid mist involve workers exposed subacutely and longer (i.e., an intermediate exposure duration). Thus, a 24-h acute ReV will be developed for chromic acid mist to be more consistent with the longer exposure duration studies available in the toxicological database for identification of an occupational POD (POD_{OC}). Consequently, in this section the TCEQ develops a health-protective, 24-h ReV and ESL based on intermediate exposure study results. Consistent with the TCEQ guidelines (2012), exceedances of the chromic acid mist short-term ESL (or long-term ESL) should be discouraged during air permit reviews as CrVI (not compound specific) has been identified as capable of causing respiratory sensitization (ATSDR 2012, Fernandez-Nieto 2006).

Consistent with the reporting of results in the key and other studies, the TCEQ will develop both acute and chronic values based on the CrVI content of chromic acid (produced from chromium trioxide) evaluated in the key study (i.e., on a CrVI equivalent basis ($\mu\text{g CrVI}/\text{m}^3$)). The CrVI equivalent for a given dose of a CrVI compound (e.g., chromic acid) is based on the percent of the compound's molecular weight that CrVI represents (i.e., the compound's concentration in $\mu\text{g}/\text{m}^3 \times (\text{MW of CrVI in compound} / \text{MW of compound})$).

3.1.1 Physical/Chemical Properties

Table 3 provides summary physical/chemical data for chromic acid (ATSDR 2008). However, it should be noted that the parameter values (e.g., molecular weight) are not for aqueous chromic acid mist and would vary with composition (e.g., percent chromium trioxide). These chemical/physical properties have toxicological implications. Human and animal inhalation exposure toxicity data indicate that chromic acid mist (e.g., soluble chromium trioxide dissolved in aqueous solution) and particulate CrVI compounds (which may be soluble or insoluble) have different adverse effect-inducing potencies and respiratory system target regions. The respiratory system is the most sensitive target for inhalation exposure to both types of CrVI compounds. However, the primary respiratory effects of chromic acid mist exposure occur in the nose, while the adverse effects of particulate CrVI compounds occur throughout the respiratory tract. Additionally, environmental exposure to chromium trioxide (or another soluble CrVI compound) in the form of chromic acid mist is less likely than environmental exposure to particulate CrVI compounds (ATSDR 2012). Thus, similar to ATSDR (2012), CalEPA (2001), and USEPA (1998), the TCEQ has derived separate noncarcinogenic inhalation ReVs for CrVI particulate compounds and chromic acid mist. *However, this DSD only provides ReVs and ESLs for chromic*

acid mist, as those for CrVI particulate compounds were presented in another DSD on hexavalent chromium and compounds (TCEQ 2014).

Please refer to TCEQ (2014) for a general discussion of the chemical/physical properties of various CrVI compounds. Regarding the physical/chemical properties of chromic acid mist more specifically, dissolving a soluble CrVI compound (e.g., chromium trioxide) in an aqueous solution yields chromic acid (H_2CrO_4). Chromium trioxide (CrO_3) is frequently used to produce chromic acid. Additional information and discussion on the chemical/physical properties of the various chromium compounds, including CrVI compounds, in relation to their toxicities may be found elsewhere (ATSDR 2012, Katz and Salem 1993).

3.1.2 Key Study for Chromic Acid Mist

The respiratory tract is the major target of inhalation exposure to CrVI compounds. In workers exposed to chromic acid mist for intermediate durations, nasal irritation, ulceration, mucosal atrophy, and rhinorrhea have been reported (ATSDR 2012).

3.1.2.1 Lindberg and Hedenstierna (1983)

Part of the following summary information on the key human study was taken, some almost verbatim, from ATSDR (2012).

The study group consisted of 85 male and 19 female chrome-plating workers (n=104) exposed to chromic acid (chromium trioxide mist). A subgroup of 37 male and 6 female chrome-plating workers (n=43) was exposed only to chromic acid and was divided into low and high 8-h mean exposure groups. The other 61 workers (48 males and 13 females) belonged to a mixed exposure group exposed to both chromic acid and other acids (e.g., hydrochloric and boric acids) and metallic (e.g., nickel, copper) salts, and were evaluated to assess potential additive or synergistic effects on lung function only. Workers were assessed for nose, throat, and chest symptoms, inspected for effects in nasal passages, and given pulmonary function tests. For pulmonary function tests, study participants were compared to a reference group of 119 auto mechanics who were not exposed to chromic acid. Nineteen office employees served as controls for the condition of the nose and throat.

The length of exposure to chromic acid ranged from 0.1 to 36 years for the study group as a whole and 0.2 to 23.6 years for the subgroup exposed to chromic acid only, spanning subacute and chronic exposure durations. *Since the study population exposed to only chromic acid included workers exposed for a subacute duration, the data were considered amenable for identification of a POD_{OC} from which to conservatively derive a 24-h acute ReV and ESL.* More specifically, the study (n=43) contained a disproportionately large number (n=23) of younger workers (ages 17-29), most of whom (n=13) were in the lowest exposure group used to identify the no-observed-adverse-effect-level (NOAEL). Therefore, the identification of a POD_{OC} from this study will be largely informed by data from younger workers in the low dose group (13 of 19) who would generally be expected to be employed and exposed for shorter durations (relative

to the study exposure duration range). Additionally, some of the higher-exposed workers mentioned they had experienced similar symptoms from the beginning of their employment (i.e., shorter-term exposure was sufficient for the onset of symptoms).

Chromium exposures were measured using personal air samplers and stationary equipment. Personal air samplers were used for 84 subjects in the study on 13 different days. Exposure for the remaining 20 workers was assumed to be similar to that measured for workers in the same area. Information on variations in exposure was also obtained from additional personal air sampler and stationary equipment data. The exposure categories were defined as high (8-h mean concentrations $\geq 2 \mu\text{g CrVI/m}^3$), low (8-h means $< 2 \mu\text{g CrVI/m}^3$), and mixed category (CrVI was $< 2 \mu\text{g CrVI/m}^3$ with exposure to other acids and metallic salts). Statistical analyses were performed using the chi-square test with Yate's correction when comparing nasal findings and the Student's two tail t-test was used when comparing lung function findings. The effects noted in the study and corresponding doses include:

- Ulcerations in the nasal mucosa and perforations of the nasal septum appeared to be better correlated with peak chromic acid concentrations ranging from 20-46 $\mu\text{g CrVI/m}^3$ than with 8-h mean concentrations, and occurred in two-thirds of the subjects exposed to these concentrations.
- Nasal irritation ($p<0.05$), mucosal atrophy ($p<0.05$), ulceration ($p<0.01$), and statistically significant ($p<0.05$) but not biologically significant decreases (1.4-8.7% Thursday afternoon compared to Monday morning) in spirometric parameters (forced vital capacity, forced expired volume in 1 second, and forced mid-expiratory flow) were observed in workers exposed to 8-h mean concentrations 2-20 $\mu\text{g CrVI/m}^3$.
- Half of the workers exposed to mean concentrations 2-20 $\mu\text{g CrVI/m}^3$ complained of a constantly running nose, a stuffy nose, "a lot to blow out," and in some cases an increased frequency of nose bleeds, pain in the nose, and phlegm in the throat; around one-third of these 24 workers were also reported to have a reddened, smeary, or crusty nasal mucosa.
- At lower 8-h means $< 2 \mu\text{g CrVI/m}^3$, a smeary and crusty septal mucosa ($p<0.05$) occurred in 11 of 19 workers. Four of the 19 workers also experienced irritation and 4 workers had an atrophied nasal mucosa at means $< 2 \mu\text{g CrVI/m}^3$, compared with 11 of 24 and 8 of 24 workers experiencing these effects, respectively, at 8-h means 2-20 $\mu\text{g CrVI/m}^3$.

These results indicate that adverse effects such as nasal irritation and associated symptomatology can occur at a high frequency in individuals exposed to 8-h chromic acid means corresponding to $\geq 2 \mu\text{g CrVI/m}^3$. These effects occur less frequently at somewhat lower concentrations. While the relationship between peak exposure and symptom manifestation was not reported to be

stronger than that observed between 8-h mean exposure and symptom development, workers exposed to peak levels between 2.5 and 11 $\mu\text{g CrVI}/\text{m}^3$ experienced nasal irritation (8 of 12) and mucosal atrophy (8 of 12) at a much greater frequency (67%) than the workers exposed to peaks between 0.2 and 1.2 $\mu\text{g CrVI}/\text{m}^3$ did (i.e., 0 of 11 experienced nasal irritation and 1 of 10 experienced mucosal atrophy). These results suggest that at least on a short-term peak basis, the threshold for these effects could be in the range of 1.2 to 2.5 $\mu\text{g CrVI}/\text{m}^3$.

In fact, the study authors reported that no worker exposed to concentrations $< 1 \mu\text{g CrVI}/\text{m}^3$ complained of symptoms (n=9), while complaints of nasal irritation were common among those exposed to 8-h means $> 1 \mu\text{g CrVI}/\text{m}^3$. These results indicate that the irritation reported for the $< 2 \mu\text{g CrVI}/\text{m}^3$ group (n=19) occurred in workers exposed to > 1 but $< 2 \mu\text{g CrVI}/\text{m}^3$, with 1.5 $\mu\text{g CrVI}/\text{m}^3$ being the midpoint. Therefore, the TCEQ considers 1.5 $\mu\text{g CrVI}/\text{m}^3$ as the approximate lowest-observed-adverse-effect-level (LOAEL) for critical effects in the upper respiratory tract (e.g., nasal symptoms/irritation) based on this study. *Furthermore, as no workers complained of symptoms, the TCEQ considers 1 $\mu\text{g CrVI}/\text{m}^3$ as the NOAEL.* The NOAEL of 1 $\mu\text{g CrVI}/\text{m}^3$ and approximate LOAEL of 1.5 $\mu\text{g CrVI}/\text{m}^3$ for nasal irritation/symptoms in Lindberg and Hedenstierna (1983) is consistent with the reported threshold for nasal irritation (1.3 $\mu\text{g CrVI}/\text{m}^3$) following “brief exposures” in an incompletely reported volunteer study of 10 subjects (Kuperman 1964 as cited by SCOEL 2004). *The NOAEL for nasal irritation and associated symptomatology (1 $\mu\text{g CrVI}/\text{m}^3$) in Lindberg and Hedenstierna (1983) will be used as the POD_{OC} for derivation of a 24-h acute ReV and ESL for chromic acid mist.*

3.1.2.2 Consideration of Developmental/Reproductive Effects

Developmental effects are considered for derivation of the acute ReV and ESL (TCEQ 2012). No inhalation exposure developmental studies were located for CrVI in humans or laboratory animals. However, due to the body’s significant capacity to reduce CrVI to CrIII, essentially detoxifying it prior to (and limiting) absorption and systemic distribution (De Flora et al. 1997), developmental effects at inhalation exposure levels lower than the lowest inhalation LOAELs for point-of-entry effects (e.g., nasal symptoms/irritation) are considered unlikely. For example, in oral studies in rats and mice, several developmental effects (e.g., decreased fetal weight and ossification, post-implantation losses, delayed sexual maturation) were observed at relatively high doses $\geq 35 \text{ mg CrVI}/\text{kg}/\text{d}$ (Section 2.2 of ATSDR 2012), which appear to significantly exceed gastrointestinal reduction capacity (TCEQ 2010). Oral doses producing such effects in mice were around 50 $\text{mg CrVI}/\text{kg}/\text{d}$ and equate to mouse daily inhalation exposure concentrations at tens of thousands $\mu\text{g CrVI}/\text{m}^3$, which are orders of magnitude higher than the concentrations (e.g., $\geq 1.5\text{-}2.0 \mu\text{g CrVI}/\text{m}^3$ as chromic acid mist) producing the critical effects observed in the key inhalation study in occupational workers (e.g., nasal symptoms/irritation). Thus, the acute ReV and ESL are expected to be protective of potential developmental effects.

Although human data on reproductive effects are limited and there is no evidence of such effects in people environmentally exposed, laboratory animal data from inhalation studies are useful. In regard to studies conducted by Glaser and colleagues, ATSDR (2012) indicates that

histopathological examination of the testes of rats exposed to 0.2 mg CrVI/m³ as sodium dichromate for 28 or 90 d (Glaser et al. 1985), to 0.1 mg CrVI/m³ as sodium dichromate for 18 months, or to 0.1 mg Cr/m³ as a 3:2 mixture of CrVI trioxide and CrIII oxide for 18 months (Glaser et al. 1986, 1988) revealed no abnormalities. No histopathological lesions were observed in the prostate, seminal vesicles, testes, or epididymides of male rats or in the uterus, mammary glands, or ovaries of female rats exposed to chromium dioxide at 15.5 mg CrVI/m³ for 2 years (Lee et al. 1989). ATSDR (2012) identified a NOAEL of 0.2 mg CrVI/m³ for reproductive effects based on the Glaser et al. (1985) study 90-d exposure duration. This reproductive inhalation NOAEL (200 µg CrVI/m³) is orders of magnitude higher than the concentrations producing portal-of-entry effects (e.g., nasal symptoms/irritation) in the key study (e.g., ≥ 1.5-2.0 µg CrVI/m³ as chromic acid mist). Thus, the acute ReV and ESL are expected to also be protective of reproductive effects.

3.1.3 Mode-of-Action (MOA) Analysis

This section contains MOA information relevant to CrVI-induced adverse effects. The following information on mechanisms of CrVI toxicity was taken from ATSDR (2008) with references omitted [*emphasis added*].

The respiratory tract is the major target of inhalation exposure to CrVI compounds in humans and animals. *Respiratory effects due to inhalation exposure are probably due to direct action of chromium at the site of contact.* The toxic potency of chromium is dependent on the oxidation state of the chromium atom, with CrVI more potent than CrIII. *The mechanisms of chromium toxicity and carcinogenicity are very complex. They are mediated partly through reactive intermediates during intracellular reduction of CrVI to CrIII and oxidative reactions, and partly mediated by CrIII which is the final product of intracellular CrVI reduction and forms deleterious complexes with critical target macromolecules.* CrIII may form complexes with peptides, proteins, and DNA, resulting in DNA-protein crosslinks, DNA strand breaks, and alterations in cellular signaling pathways, which may contribute to toxicity and carcinogenicity of chromium compounds.

The greater toxic potency of CrVI relative to CrIII most likely is related to two factors: (1) the higher redox potential of CrVI; and (2) the greater ability of CrVI to enter cells. Differences in molecular structure contribute the greater cellular uptake of CrVI compared to CrIII. At physiological pH, CrVI exists as the tetrahedral chromate anion, resembling the forms of other natural anions (e.g., sulfate and phosphate) which are permeable across nonselective membrane channels. CrIII, however, forms octahedral complexes and cannot easily enter through these channels. Therefore, the lower toxicity to CrIII may be due in part to lack of penetration through cell membranes. It follows that extracellular reduction of CrVI to CrIII may result in a decreased penetration of chromium into cells, and therefore, a decreased toxicity.

The higher redox potential of CrVI contributes to the higher toxic potency of CrVI relative to CrIII, because once it is taken into cells, CrVI is rapidly reduced to CrIII, with CrV and CrIV as intermediates. These reactions commonly involve intracellular species, such as ascorbate, glutathione, or amino acids. CrVI, CrV, and CrIV have all been shown to be involved in Fenton-like oxidative cycling, generating oxygen radical species. It is believed that the formation of these radicals may be responsible for many of the deleterious effects of chromium on cells, including lipid peroxidation and alterations in cellular communication, signaling pathways and cytoskeleton. Cellular damage from exposure to many chromium compounds can be blocked by radical scavengers, further strengthening the hypothesis that oxygen radicals play a key role in chromium toxicity.

To summarize, while the toxic potential of chromium following inhalation exposure is dependent on the oxidation state and any resulting adverse effects are probably due to the direct action of chromium at the site of contact, the mechanisms of chromium toxicity appear very complex and are mediated partly: (1) through reactive intermediates during intracellular reduction of CrVI to CrIII and oxidative reactions, and (2) by CrIII which is the final product of intracellular CrVI reduction and forms deleterious complexes with critical target macromolecules that may contribute to toxicity and carcinogenicity of chromium compounds. CrVI is more toxic than CrIII due to a greater ability to enter cells where it and its metabolic intermediates (CrV, CrIV) formed during rapid reduction to CrIII generate oxygen radical species believed to be responsible for many of the deleterious effects of chromium on cells.

Finally, because chromic acid is a strong corrosive, it has the potential to cause damage to tissues of the mucous membranes and upper respiratory tract.

3.1.4 POD, Critical Effect, and Dose Metric

The TCEQ considers $1 \mu\text{g CrVI}/\text{m}^3$ as the NOAEL for the critical effects observed in the upper respiratory tract (e.g., nasal symptoms/irritation) based on the key study of Lindberg and Hedenstierna (1983), which will be used as a POD_{OC} for derivation of the acute ReV and ESL. Additionally, as is often the case for inhalation studies, air concentration was the only dose metric available from the key study. Therefore, air concentration was used as the default dose metric for derivation of the acute ReV and ESL for chromic acid mist.

3.1.5 Dosimetric Adjustment

3.1.5.1 Potential Exposure Duration Adjustment

Upward adjustment of the POD_{OC} from the intermediate (i.e., subacute and longer) exposure duration in the key study to the shorter, 24-h acute ReV duration of interest is not possible in a toxicologically predictive manner. Therefore, no duration adjustments will be performed to the POD_{OC} , which will serve as the human equivalent concentration POD (POD_{HEC}). The TCEQ notes that use of a POD_{HEC} from an intermediate duration study for derivation of a 24-h ReV

may be conservative. For example, the shortest exposure duration for the subgroup exposed to chromic acid only was 0.2 years or about 10 weeks, which would be estimated to include approximately 50 work days and 400 h of potential exposure. Use of a study wherein workers were exposed ≥ 400 h to develop a 24-h ReV may be considered conservative as several of the adverse effects noted are due to repeated daily exposure (e.g., nasal mucosal atrophy and ulceration) and would contribute to the nasal symptomatology reported (e.g., nasal irritation, smeary/crusty mucosa). On the other hand, some of the higher-exposed workers mentioned they had experienced symptoms from the beginning of their employment, and the “brief exposure” nasal irritation threshold from an incompletely reported volunteer study (Kuperman 1964 as cited by SCOEL 2004) falls between the key study NOAEL and LOAEL. Based on this information, the TCEQ considers use of a POD_{HEC} from the intermediate duration key study of Lindberg and Hedenstierna (1983) as reasonable for derivation of a 24-h acute ReV and ESL.

$$POD_{HEC} = 1 \mu\text{g CrVI}/\text{m}^3 \text{ (NOAEL)}$$

3.1.5.2 Adjustments of the POD_{HEC}

For noncarcinogenic effects, a POD is determined and appropriate uncertainty factors (UFs) are applied to derive the acute ReV (i.e., assume a threshold MOA) (TCEQ 2012).

The following UFs were applied to the POD_{HEC} (NOAEL) derived from the key study of Lindberg and Hedenstierna (1983):

- A UF_H of 10 for interindividual variability because the study population did not include potentially sensitive subpopulations such as children, the elderly, and those with pre-existing medical conditions.
- A UF_D of 1 was used for database uncertainty because a much longer duration study (all workers ≥ 400 h of exposure) was used to determine a 24-h acute ReV. This approach is generally considered conservative (i.e., health-protective) and mitigates the lack of more short-term (e.g., ≤ 1 day) studies. Additionally, information is available regarding the potential for CrVI-induced developmental and reproductive effects (Section 3.1.2.2) which suggests that such effects are unlikely at inhalation exposure levels lower than the lowest inhalation LOAELs for portal-of-entry effects.

Consequently, a total UF of 10 was applied to the POD_{HEC} to derive the acute ReV:

$$\begin{aligned} \text{24-h acute ReV} &= POD_{HEC} / (UF_H \times UF_D) \\ &= 1 \mu\text{g CrVI}/\text{m}^3 / (10 \times 1) \\ &= 0.1 \mu\text{g CrVI}/\text{m}^3 \text{ based on CrVI content of chromic acid mist} \end{aligned}$$

Thus, when rounded to two significant figures, the 24-h acute ReV for chromic acid mist based on CrVI content is $0.10 \mu\text{g CrVI}/\text{m}^3$.

3.1.6 Health-Based Acute ReV and ^{acute}ESL

The 24-h acute ReV is 0.10 µg CrVI/m³ for chromic acid mist based on CrVI content. The 24-h acute ReV was then used to calculate the 24-h ^{acute}ESL. At the target hazard quotient (HQ) of 0.3, the 24-h ^{acute}ESL for chromic acid mist based on CrVI content is 0.030 µg CrVI/m³ (Table 4).

Table 4. Derivation of the 24-h Acute ReV and ^{acute}ESL

Parameter	Summary
Key Study	Lindberg and Hedenstierna (1983)
Study Population	37 male and 6 female chrome-plating workers exposed to chromic acid
Study Quality Confidence Level	Medium
Exposure Method	Occupational workplace exposure
Critical Effects	Upper respiratory tract effects (e.g., nasal symptoms/irritation)
POD _{OC}	1 µg CrVI/m ³ (NOAEL)
Exposure Duration	8 h/day, 5 days per week, 0.2-23.6 years (2.5-year median)
Extrapolation to 24-h	None conducted
POD _{HEC}	1 µg CrVI/m ³
Total uncertainty factors (UFs)	10
<i>Intraspecies UF</i>	<i>10</i>
<i>Incomplete Database UF</i>	<i>1</i>
<i>Database Quality</i>	<i>Medium</i>
24-h Acute ReV (HQ = 1)	0.10 µg CrVI/m³
24-h ^{acute}ESL (HQ = 0.3)	0.030 µg CrVI/m³

3.1.7 Comparison of Results

No acute, health-protective ambient air concentrations for CrVI have been derived by agencies such as USEPA, CalEPA, and ATSDR. However, ATSDR (2012) has calculated an intermediate duration inhalation minimal risk level (MRL for 15-364 days) of 0.005 µg CrVI/m³ for chromic acid/dissolved CrVI mist based on the same key study as the TCEQ used to derive the 24-h ReV.

The TCEQ's acute 24-h ReV for chromic acid mist based on CrVI content is $0.10 \mu\text{g CrVI}/\text{m}^3$, which is 20-fold higher than ATSDR's intermediate (15-364 day) MRL. The main differences are that:

- ATSDR used a LOAEL of $2 \mu\text{g CrVI}/\text{m}^3$ whereas the TCEQ used a NOAEL of $1 \mu\text{g CrVI}/\text{m}^3$;
- ATSDR adjusted to continuous exposure since they were deriving a value for up to 364 days of constant exposure; and
- ATSDR used a UF_L of 10 whereas this UF was not applicable to TCEQ's derivation which used a NOAEL.

Consequently, ATSDR's use of the LOAEL with a UF_L of 10 and adjustment to continuous 364-day exposure (not needed when TCEQ extrapolates from hundreds of hours of exposure to a 24-h period) are the primary contributors to the difference in values. Thus, when considering the different methodologies and exposure durations (i.e., 24 h for TCEQ's ReV versus up to 8,736 h for ATSDR's MRL, a factor of 364), a comparison of the TCEQ's 20-fold higher 24-h ReV to the intermediate MRL shows the TCEQ value to be health-protective and appropriately conservative.

3.2 Welfare-Based Acute ESLs

3.2.1 Odor Perception

Odor information is not available for chromic acid (Table 3).

3.2.2 Vegetation Effects

No useful data were found regarding potential adverse vegetative effects due to direct exposure to airborne CrVI.

3.3 Acute Values for Air Permitting and Air Monitoring Evaluations

This acute evaluation resulted in the derivation of the following acute values:

- 24-h acute ReV = $0.10 \mu\text{g CrVI}/\text{m}^3$ based on the CrVI content of chromic acid mist
- 24-h ^{acute}ESL = $0.030 \mu\text{g CrVI}/\text{m}^3$ based on the CrVI content of chromic acid mist

The 24-h ^{acute}ESL for air permit evaluations is $0.03 \mu\text{g CrVI}/\text{m}^3$ (Table 2). Chromic acid mist is not specifically monitored for in ambient air. Since the general public has a limited potential for exposure to chromic acid mist and the most likely environmental CrVI exposures are to particulate CrVI compounds (ATSDR 2012), please refer to the DSD on hexavalent chromium and compounds (Table 1 in TCEQ 2014) for AMCVs for review of any CrVI ambient air

monitoring data. In the unlikely event that chromic acid is monitored for specifically in ambient air in the future, the 24-h ReV of $0.10 \mu\text{g CrVI}/\text{m}^3$ will be used for the evaluation of air monitoring data (Table 1), not the ^{acute}ESL. In general, to protect against sensitization, exceedances of the acute (or chronic) ESL during the air permit review should be discouraged for any chemicals identified as respiratory sensitizers (TCEQ 2012).

3.4 Subacute Inhalation Observed Adverse Effect Level

Environmental exposure to CrVI in the form of chromic acid mist (e.g., chromium trioxide in the form of chromic acid mist) is less likely than environmental exposure to particulate CrVI compounds (ATSDR 2012). Additionally, while limited ambient air data are collected for CrVI in the form of particulate, chromic acid mist is not specifically monitored. Nevertheless, Section 3.13 of TCEQ (2012) indicates that when adequate data exist for inhalation, the TCEQ will provide inhalation observed adverse effect levels. The key study for derivation of the 24-h ReV for chromic acid mist was a human study spanning subacute and chronic exposure durations and will be used to derive a subacute (i.e., not 24 h) inhalation observed adverse effect level. As the basis for development of inhalation observed adverse effect levels is limited to available data, future studies could possibly identify a lower POD for this purpose.

Based on the discussion of the key human study (Lindberg and Hedenstierna 1983) in Section 3.1.2.1, the TCEQ considers $1.5 \mu\text{g CrVI}/\text{m}^3$ as the approximate LOAEL for nasal irritation/symptoms (e.g., crusty septal mucosa). These critical effects were associated with 8 h/day, 5 day per week exposure for 0.2-23.6 years (2.5-year median) for those exposed only to chromic acid mist (e.g., chromium trioxide in the form of chromic acid mist), spanning subacute and chronic exposure durations. However, as discussed previously, the identification of POD_{OC} values (e.g., NOAEL/LOAEL) from this study was largely informed by data from younger workers in the low dose group who would generally be expected to be employed and exposed for shorter durations (relative to the study exposure duration range). Therefore, the TCEQ will consider 10 weeks (≈ 0.2 years), which represents the lower end of the worker exposure duration range, as the shortest exposure duration potentially associated with the critical effects observed in the study at the approximate LOAEL.

The LOAEL of $1.5 \mu\text{g CrVI}/\text{m}^3$ based on the human study of Lindberg and Hedenstierna (1983) represents a concentration at which it is probable that similar effects could occur in some individuals exposed to this level over the same durations as in the study (8 h/day, 5 day per week exposure for ≥ 10 weeks). Importantly, effects are not a certainty due to potential intrahuman differences in sensitivity (also, it is not known that workers exposed only for 0.2 years (≈ 10 weeks) were among those reporting symptoms). The estimated subacute (i.e., not 24 h) inhalation observed adverse effect level of $1.5 \mu\text{g CrVI}/\text{m}^3$ based on the CrVI content of chromic acid mist is provided for informational purposes only (TCEQ 2012).

The margin of exposure between the estimated subacute (i.e., not 24 h) inhalation observed adverse effect level of 1.5 $\mu\text{g CrVI}/\text{m}^3$ and the 24-h acute ReV of 0.10 $\mu\text{g CrVI}/\text{m}^3$ is a factor of 15.

Chapter 4 Chronic Evaluation

4.1 Noncarcinogenic Potential

As indicated previously (Section 3.1.1), similar to other agencies (e.g., ATSDR, CalEPA, USEPA), the TCEQ has derived separate noncarcinogenic inhalation ReVs for chromic acid mist and CrVI particulate compounds. *This DSD only provides ReVs for chromic acid mist, as those for CrVI particulate compounds were presented in another DSD on hexavalent chromium and compounds (TCEQ 2014).*

Most of the following two paragraphs was taken, much of it verbatim, from the summary of the chronic human and animal toxicological literature provided in ATSDR (2012) with most references omitted for brevity [*emphasis added*].

The chronic-duration inhalation database for humans exposed to dissolved CrVI mists consists of occupational exposure studies on *chromium trioxide mist (a.k.a., chromic acid mist)*, reporting effects to the respiratory, renal, and gastrointestinal systems (Lindberg and Hedenstierna 1983, Gibb et al. 2000a). *Respiratory effects included bleeding nasal septum, nasal mucosal atrophy, nasal septal ulceration and perforation, epistaxis, rhinorrhea, and decreased lung function, with LOAEL values ranging from 0.002 to 0.414 mg CrVI/m³.* Effects indicative of renal toxicity include increased retinol binding protein and tubular antigen and increased urinary β -2-microglobulin (Lindberg and Hedenstierna 1983); LOAEL values for these effects range from 0.004 to 0.05 mg CrVI/m³. Gastrointestinal effects reported in workers include stomach pains, cramps, and ulcers, with a LOAEL value of 0.004 mg CrVI/m³. Other effects specific for dissolved CrVI mists in humans exposed for chronic exposure durations have not been reported. Exposure to CrVI compounds (not compound-specific) can produce allergic sensitization, which may manifest as symptoms of asthma upon subsequent inhalation exposures. Studies in animals evaluating the effects of chronic-duration exposure to dissolved CrVI mists were not identified.

Based on a comparison of LOAEL values for respiratory, renal, and gastrointestinal effects in workers, the respiratory tract was identified as the most sensitive effect of chronic-duration inhalation exposure. *The lowest LOAEL value of 0.002 mg CrVI/m³ was reported for nasal irritation, mucosal atrophy, and ulceration and decreases in spirometric parameters in workers occupationally exposed to chromic acid mist (Lindberg and Hedenstierna 1983).* The population evaluated in this study had a median exposure duration of 2.5 years, with a range of 0.1–23.6 years.

ATSDR (2012), CalEPA (2001), and USEPA (1998) all developed a chronic inhalation value for chromic acid/dissolved CrVI mist based on the upper respiratory tract effects observed in the key study of Lindberg and Hedenstierna (1983). The TCEQ agrees that this study provides the most information on exposure levels and symptoms (e.g., nasal mucosal irritation, atrophy, ulceration and perforation, pulmonary function) reported for workers exposed to chromic acid mist and is the best available human study. *Thus, the noncarcinogenic chronic ReV and ^{chronic}ESL_{threshold(nc)} values for chromic acid mist will be based Lindberg and Hedenstierna (1983) as the key study.*

As mentioned in Section 3.1, consistent with the reporting of results in the key and other studies, the TCEQ will develop chronic values (in addition to acute values) based on the CrVI content of chromic acid (produced from chromium trioxide) used in the key study (i.e., on a CrVI equivalent basis). The CrVI equivalent for a given dose of a CrVI compound (e.g., chromic acid) is based on its CrVI content, that is, the percent of the compound's molecular weight that CrVI represents (e.g., the compound's concentration in $\mu\text{g}/\text{m}^3 \times (\text{MW of CrVI in compound} / \text{MW of compound})$).

4.1.1 Key Study for Chromic Acid Mist

4.1.1.1 Lindberg and Hedenstierna (1983)

Similar to ATSDR (2012), CalEPA (2001), and USEPA (1998), the TCEQ will utilize the key study of Lindberg and Hedenstierna (1983) to develop a health-protective, chronic inhalation value for chromic acid mist. See Section 3.1.2.1 for the study summary. In brief, the reported key findings include:

- Ulcerations in the nasal mucosa and perforations of the nasal septum appeared to be better correlated with peak chromic acid concentrations ranging from 20-46 $\mu\text{g CrVI}/\text{m}^3$ than with 8-h mean concentrations, and occurred in two-thirds of the subjects exposed to these concentrations.
- Nasal irritation ($p < 0.05$), mucosal atrophy ($p < 0.05$), ulceration ($p < 0.01$), and statistically significant ($p < 0.05$) but not biologically significant decreases (1.4-8.7% Thursday afternoon compared to Monday morning) in spirometric parameters (forced vital capacity, forced expired volume in 1 second, and forced mid-expiratory flow) were observed in workers exposed to 8-h mean concentrations 2-20 $\mu\text{g CrVI}/\text{m}^3$.
- Half of the workers exposed to mean concentrations 2-20 $\mu\text{g CrVI}/\text{m}^3$ complained of constantly running noses, stuffy noses, "a lot to blow out," and in some cases an increased frequency of nose bleeds, pain in the nose, and phlegm in the throat, and around one-third of these 24 workers were also reported to have a reddened, smeary, or crusty nasal mucosa.

- At lower 8-h means $< 2 \mu\text{g CrVI}/\text{m}^3$, a smeary and crusty septal mucosa ($p < 0.05$) occurred in 11 of 19 workers. Four of the 19 workers also experienced irritation and 4 workers had an atrophied nasal mucosa at means $< 2 \mu\text{g CrVI}/\text{m}^3$, compared with 11 of 24 and 8 of 24 workers experiencing these effects, respectively, at 8-h means 2-20 $\mu\text{g CrVI}/\text{m}^3$.

These results indicate that adverse effects such as nasal irritation/symptomatology can occur very frequently at daily 8-h chronic acid means corresponding to $\geq 2 \mu\text{g CrVI}/\text{m}^3$ and less frequently at somewhat lower concentrations. The study authors reported that no worker exposed to concentrations $< 1 \mu\text{g CrVI}/\text{m}^3$ complained of symptoms ($n=9$), while complaints of nasal irritation were common among those exposed to daily 8-h means $> 1 \mu\text{g CrVI}/\text{m}^3$. These results indicate that the irritation reported for the $< 2 \mu\text{g CrVI}/\text{m}^3$ group ($n=19$) occurred in workers exposed to > 1 but $< 2 \mu\text{g CrVI}/\text{m}^3$, with $1.5 \mu\text{g CrVI}/\text{m}^3$ being the midpoint. Thus, the TCEQ considers $1.5 \mu\text{g CrVI}/\text{m}^3$ as the approximate LOAEL for critical effects in the upper respiratory tract (e.g., nasal symptoms/irritation) based on this study. *Furthermore, based on the absence of symptoms, the TCEQ considers $1 \mu\text{g CrVI}/\text{m}^3$ as the NOAEL.* With a median study exposure duration of 2.5 years, this value is a subchronic NOAEL.

The NOAEL for nasal symptomatology in this key study ($1 \mu\text{g CrVI}/\text{m}^3$) will be used as the subchronic POD_{OC} for derivation of a chronic noncarcinogenic ReV and ^{chronic} $\text{ESL}_{\text{threshold(nc)}}$.

4.1.1.2 Consideration of Developmental/Reproductive Effects

Developmental and reproductive effects are considered for derivation of the chronic ReV and ESL (TCEQ 2012). However, such effects at low exposure levels are considered unlikely due to the body's apparent significant capacity to reduce CrVI to CrIII, essentially detoxifying it prior to (and limiting) absorption and systemic distribution (De Flora et al. 1997). As discussed in Section 3.1.2.2 of the acute assessment, while no inhalation studies with developmental/reproductive LOAELs are available to assess these endpoints, the oral doses producing developmental effects equate to daily inhalation exposure concentrations which are thousands of times higher than the levels producing the critical effects observed in the key study (e.g., nasal symptoms/irritation). Additionally, the inhalation NOAEL for reproductive effects identified by ATSDR (2012) is also orders of magnitude greater than the LOAEL for nasal symptoms/irritation in the key study. Thus, the chronic ReV and ESL are expected to be protective of developmental and reproductive effects.

4.1.2 MOA Analysis

General information on the MOA(s) through which CrVI may induce adverse effects is discussed in Section 3.1.3. As with many chemicals, a complete and clear picture of the underlying mechanisms and/or MOA(s) producing the noncarcinogenic adverse effects of CrVI is still to be fully elucidated. Lastly, because chromic acid is a strong corrosive, it has the potential to cause damage to tissues of the mucous membranes and upper respiratory tract.

4.1.3 POD, Critical Effect, and Dose Metric

The TCEQ considers $1 \mu\text{g CrVI}/\text{m}^3$ as the NOAEL for the critical effects observed in the upper respiratory tract (e.g., nasal symptoms/irritation) based on the key study of Lindberg and Hedenstierna (1983), which will be used as a subchronic POD_{OC} for derivation of the chronic ReV and $\text{chronic ESL}_{\text{threshold(nc)}}$. Additionally, as is often the case for inhalation studies, air concentration was the only dose metric available from the key study. Therefore, air concentration was used as the default dose metric for derivation of the acute ReV and ESL for chronic acid mist.

4.1.4 Dosimetric Adjustment

4.1.4.1 Exposure Duration Adjustment

For derivation of the chronic ReV and $\text{chronic ESL}_{\text{threshold(nc)}}$, the subchronic NOAEL-based POD_{OC} from the key study (Lindberg and Hedenstierna 1983) was adjusted to continuous exposure applicable to the general population (POD_{HEC}) per TCEQ (2012):

$$\text{POD}_{\text{HEC}} = \text{POD}_{\text{OC}} \times (\text{VE}_{\text{ho}}/\text{VE}_{\text{h}}) \times (\text{days per week}_{\text{oc}}/\text{days per week}_{\text{res}})$$

where: VE_{ho} = occupational ventilation rate for an 8-h day ($10 \text{ m}^3/\text{day}$)
 VE_{h} = non-occupational ventilation rate for a 24-h day ($20 \text{ m}^3/\text{day}$)
 $\text{days per week}_{\text{oc}}$ = occupational weekly exposure frequency (study specific)
 $\text{days per week}_{\text{res}}$ = residential weekly exposure frequency (7 days per week)

$$\text{POD}_{\text{HEC}} = 1 \mu\text{g CrVI}/\text{m}^3 \times (10/20) \times (5/7) = 0.3571 \mu\text{g CrVI}/\text{m}^3$$

4.1.4.2 Adjustment of the POD_{HEC}

For noncarcinogenic effects, a POD is determined and appropriate UFs are applied to derive the chronic ReV (i.e., assume a threshold MOA) (TCEQ 2012).

The following UFs were applied to the POD_{HEC} (NOAEL) derived from the key study of Lindberg and Hedenstierna (1983):

- A UF_{H} of 10 was used for interindividual variability because the study population did not include potentially sensitive subpopulations such as children, the elderly, and those with pre-existing medical conditions; additionally, CrVI has the potential to be a sensitizer.
- A UF_{Sub} of 1 was used for extrapolation from subchronic to chronic exposure since the study included some chronically exposed workers (e.g., up to 23.6 years for the subgroup exposed to chromic acid only), toxicokinetic considerations (e.g., the body's ability to reduce CrVI to CrIII to limit absorption and systemic distribution) help reduce concern about chronic noncarcinogenic effects differing significantly from subchronic effects, and the median exposure duration of 2.5 years appears sufficient in regards to observation of

the response level for the critical effects (workers in subchronic studies tend to begin experiencing such symptoms fairly early on in exposure (e.g., around 90 days on average in Gibb et al. 2000a)).

- A reduced UF_D of 3 was considered applicable for database deficiency because although studies relevant to a chronic noncarcinogenic assessment of chromic acid mist and the identification of associated PODs are limited, available information regarding the potential for CrVI-induced developmental and reproductive effects (Section 4.1.1.2) suggests that such effects are unlikely at inhalation exposure levels lower than the lowest inhalation LOAELs for portal-of-entry effects.

Consequently, consistent with TCEQ (2012), a total UF of 30 was applied to the POD_{HEC} to derive the chronic noncarcinogenic ReV:

$$\begin{aligned}\text{chronic ReV} &= POD_{HEC} / (UF_H \times UF_{Sub} \times UF_D) \\ &= 0.3571 \mu\text{g CrVI}/\text{m}^3 / (10 \times 1 \times 3) \\ &= 0.0119 \mu\text{g CrVI}/\text{m}^3 \text{ based on CrVI content of chromic acid mist}\end{aligned}$$

Thus, when rounded to two significant figures consistent with TCEQ (2012), the chronic ReV for chromic acid mist based on CrVI content is $0.012 \mu\text{g CrVI}/\text{m}^3$.

4.1.5 Health-Based Chronic ReV and $^{chronic}ESL_{threshold(nc)}$

The chronic ReV is $0.012 \mu\text{g CrVI}/\text{m}^3$ based on CrVI content for chromic acid mist. The rounded chronic ReV was then used to calculate the $^{chronic}ESL_{threshold(nc)}$. At the target HQ of 0.3, the rounded $^{chronic}ESL_{threshold(nc)}$ is $0.0036 \mu\text{g CrVI}/\text{m}^3$ (Table 5).

Table 5. Derivation of the Chronic ReV and ^{chronic}ESL_{threshold(nc)}

Parameters	Summary
Key Study	Lindberg and Hedenstierna (1983)
Study Population	37 male and 6 female chrome-plating workers exposed to chromic acid
Study Quality Confidence Level	Medium
Exposure Method	Occupational workplace exposure
Critical Effects	Upper respiratory tract effects (e.g., nasal symptoms/irritation)
POD _{OC}	1 µg CrVI/m ³ (NOAEL)
Exposure Duration	8 h/day, 5 days per week, 2.5-year median
POD _{HEC}	POD _{HEC} = 1 µg CrVI/m ³ x (10/20) x (5/7) = 0.3571 µg CrVI/m ³
Total uncertainty factors (UFs)	30
<i>Intraspecies UF</i>	10
<i>Subchronic UF</i>	1
<i>Incomplete Database UF</i>	3
<i>Database Quality</i>	Medium
Chronic ReV (HQ = 1)	0.012 µg CrVI/m³
^{chronic}ESL_{threshold(nc)} (HQ = 0.3)	0.0036 µg CrVI/m³

4.1.6 Comparison of Results

Chronic health-protective air concentrations for CrVI have been derived by agencies such as USEPA, CalEPA, and ATSDR. However, ATSDR (2012) represents the most recent noncarcinogenic inhalation assessment. ATSDR (2012) has calculated a chronic inhalation MRL of 0.005 µg CrVI/m³ for chromic acid/dissolved CrVI mist based on the same key study as the TCEQ used to derive the chronic ReV. The TCEQ's chronic ReV for chromic acid mist based on CrVI content is 0.012 µg CrVI/m³, which is 2.4-fold higher. The main differences are that:

- ATSDR used a LOAEL of 2 µg CrVI/m³ with a UF_L of 10 whereas the TCEQ used a NOAEL of 1 µg CrVI/m³; and

- ATSDR adjusted to continuous exposure partly using a 8 h/24 h term while TCEQ (2012) uses an occupational-to-environmental ventilation rate ratio term of $10 \text{ m}^3/20 \text{ m}^3$ instead (both in addition to a 5 day/7 day term).

Consequently, ATSDR's adjustment to continuous exposure results in a slightly lower POD_{HEC} . Both agencies use a full UF_H of 10. When considering the different methodologies and application of appropriate UFs by the TCEQ, a comparison of TCEQ's slightly higher chronic ReV to the chronic MRL shows the TCEQ value to be health-protective.

TCEQ chronic ReVs can also be compared to USEPA chronic reference concentrations (RfCs) and CalEPA chronic reference exposure levels (RELs). The USEPA (1998) chronic RfC ($0.008 \mu\text{g CrVI}/\text{m}^3$) for chromic acid/dissolved CrVI mist is 1.5-fold lower than TCEQ's chronic ReV, while the CalEPA (2001) chronic REL ($0.002 \mu\text{g CrVI}/\text{m}^3$) for chromic acid mist is 6 times lower. On the other hand, TCEQ's $\text{chronicESL}_{\text{threshold(nc)}}$ of $0.0036 \mu\text{g CrVI}/\text{m}^3$, which is applicable to air permit reviews of any off-site impacts of chromic acid mist emissions (based on CrVI content), is 2.2-fold lower than the USEPA value and 1.8-fold higher than the CalEPA value.

4.2 Carcinogenic Potential

An assessment of the carcinogenic potential of CrVI is contained in another DSD on hexavalent chromium and compounds (TCEQ 2014). The TCEQ considers CrVI and CrVI compounds as a group to be *carcinogenic to humans* via inhalation (at least at sufficiently high long-term doses). The TCEQ's weight of evidence (WOE) classification is applied to all forms of CrVI, including chromic acid mist (e.g., chromium trioxide in the form of chromic acid). This is because although sparingly soluble forms are likely to represent a more significant cancer hazard, there is evidence suggesting that soluble CrVI (e.g., chromic acid mists in the plating industry) produces an increased risk of lung cancer (ATSDR 2012).

The DSD on hexavalent chromium and compounds (TCEQ 2014) derived a final inhalation unit risk factor (URF) of $2.3\text{E}-03$ per $\mu\text{g CrVI}/\text{m}^3$ for environmental exposure to CrVI based on occupational lung cancer mortality data from Crump et al. (2003) and Gibb et al. (2000b). Based on the WOE classification, this URF is applicable to CrVI in all forms of CrVI, including chromic acid mist. The corresponding air concentration at a no significant risk level of 1 in 100,000 excess cancer risk is $0.0043 \mu\text{g CrVI}/\text{m}^3$. Thus, the $\text{chronicESL}_{\text{nonthreshold(c)}}$ is $0.0043 \mu\text{g CrVI}/\text{m}^3$.

4.3 Welfare-Based Chronic ESL

Vegetation Effects

No useful data were found regarding potential adverse vegetative effects due to direct exposure to airborne CrVI.

4.4 Chronic Values for Air Permitting and Air Monitoring Evaluations

The chronic evaluation resulted in the derivation of the following chronic values:

- chronic ReV = 0.012 $\mu\text{g CrVI}/\text{m}^3$ based on the CrVI content of chromic acid mist
- $\text{chronicESL}_{\text{threshold(nc)}} = 0.0036 \mu\text{g CrVI}/\text{m}^3$ based on the CrVI content of chromic acid mist
- $\text{chronicESL}_{\text{nonthreshold(c)}} = 0.0043 \mu\text{g CrVI}/\text{m}^3$ for all forms of CrVI (TCEQ 2014)

The chronic ESL for air permit evaluations is the $\text{chronicESL}_{\text{threshold(nc)}}$ of 0.0036 $\mu\text{g CrVI}/\text{m}^3$ as it is slightly lower than the $\text{chronicESL}_{\text{nonthreshold(c)}}$ of 0.0043 $\mu\text{g CrVI}/\text{m}^3$ for CrVI (Table 2). Chromic acid mist is not specifically monitored for in ambient air. Since the general public has a limited potential for exposure to chromic acid mist and the most likely environmental CrVI exposures are to particulate CrVI compounds (ATSDR 2012), please refer to the DSD on hexavalent chromium and compounds (Table 1 in TCEQ 2014) for AMCVs for review of any CrVI ambient air monitoring data. In the unlikely event that chromic acid mist is monitored for specifically in ambient air in the future, the $\text{chronicESL}_{\text{nonthreshold(c)}}$ of 0.0043 $\mu\text{g CrVI}/\text{m}^3$ is lower than the chronic ReV of 0.012 $\mu\text{g CrVI}/\text{m}^3$ (Table 1). The $\text{chronicESL}_{\text{threshold(nc)}}$ (HQ = 0.3) value is not used to evaluate ambient air monitoring data. As indicated previously, to protect against sensitization, exceedances of the chronic (or acute) ESL during the air permit review should be discouraged for any chemicals identified as respiratory sensitizers (TCEQ 2012).

4.5 Subchronic Inhalation Observed Adverse Effect Level

Environmental exposure to CrVI in the form of chromic acid mist (e.g., chromium trioxide in the form of chromic acid mist) is less likely than environmental exposure to particulate CrVI compounds (ATSDR 2012). Additionally, while limited ambient air data are collected for CrVI in the form of particulate, chromic acid mist is not specifically monitored. Nevertheless, Section 3.13 of TCEQ (2012) indicates that when adequate data exist for inhalation, the TCEQ will provide inhalation observed adverse effect levels. The key study for derivation of the chronic ReV for chromic acid mist was a human study with a subchronic exposure duration median of 2.5 years and will be used to derive a subchronic inhalation observed adverse effect level. As the basis for development of inhalation observed adverse effect levels is limited to available data, future studies could possibly identify a lower POD for this purpose.

Based on the discussion of the key human study (Lindberg and Hedenstierna 1983) in Section 4.1.1.1, the TCEQ considers 1.5 $\mu\text{g CrVI}/\text{m}^3$ as the approximate LOAEL for nasal irritation/symptoms (e.g., crusty septal mucosa). These critical effects were associated with 8 h/day, 5 day per week exposure for 0.2-23.6 years with a 2.5-year (subchronic) median for those exposed only to chromic acid mist (e.g., chromium trioxide in the form of chromic acid mist). The LOAEL of 1.5 $\mu\text{g CrVI}/\text{m}^3$ represents a concentration at which it is probable that similar effects could occur in some individuals exposed to this level over the same subchronic durations as in the study (e.g., the exposure median of 2.5 years) or longer. However, as discussed in Section 3.4, it should be

noted that this same inhalation observed adverse effect level applies to subacute exposure (≈ 10 weeks). Importantly, effects are not a certainty due to potential intrahuman differences in sensitivity. The estimated subchronic inhalation observed adverse effect level of $1.5 \mu\text{g CrVI}/\text{m}^3$ based on the CrVI content of chromic acid mist is provided for informational purposes only (TCEQ 2012).

The margin of exposure between the estimated subchronic inhalation observed adverse effect level of $1.5 \mu\text{g CrVI}/\text{m}^3$ and the chronic ReV of $0.012 \mu\text{g CrVI}/\text{m}^3$ is a factor of 125.

Chapter 5 References

5.1. References Cited in DSD

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