



**New Jersey  
Department of Environmental Protection**

**INDOOR AIR REMEDIATION STANDARDS  
FOR THE VAPOR INTRUSION EXPOSURE  
PATHWAY**

**BASIS AND BACKGROUND**

**May 2021**

## Table of Contents

1. Introduction.....	3
2. Methodology for Developing the Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway.....	3
2.1. Overview.....	3
2.2. Equations.....	4
2.2.1. Mutagenic Mode of Action.....	5
2.3. Toxicity Factors .....	6
2.3.1. Route-to-Route Extrapolation.....	6
2.3.2. Ethylbenzene.....	7
2.4. Exposure Parameters.....	8
2.5. Group C Carcinogen Policy.....	8
2.6. Calculations.....	9
3. Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway .....	10
3.1. Determination of Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway .....	10
3.2. Air Analytical Reporting Limits .....	10
4. Alternative Remediation Standards (ARS) for Indoor Air for the Vapor Intrusion Exposure Pathway .....	10
5. Interim Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway.....	11
References.....	12

## Tables

Table 1 Indoor Air Toxicity Factors .....	15
Table 2 Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway - Residential ( $\mu\text{g}/\text{m}^3$ ) (All numeric values are rounded to two significant figures).....	23
Table 3 Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway - Nonresidential ( $\mu\text{g}/\text{m}^3$ ) (All numeric values are rounded to two significant figures).....	25

## 1. Introduction

The Department utilizes the risk-based approach outlined in the United States Environmental Protection Agency's (USEPA's) *Risk Assessment Guidance for Superfund, Part F: Supplemental Guidance for Inhalation Risk Assessment* (RAGS Part F) (USEPA 2009) in the development of the Indoor Air Remediation Standards (IARS) for the vapor intrusion (VI) exposure pathway. VI is defined as the migration of volatile chemicals from the subsurface into overlying buildings (USEPA 2002). VI has the potential to adversely impact the health of building occupants through possible chronic inhalation of elevated levels of volatile contaminants migrating into the building from contaminated soil, soil gas and/or ground water.

The purpose for promulgating the IARS is to codify in regulations indoor air levels to be used in the evaluation and remediation of the VI exposure pathway at contaminated sites. The IARS list of contaminants is based on those constituents included in the USEPA Volatile Organic Compounds (VOC) Target Compound List (TCL) and the NJDEP-SRP Low Level USEPA TO-15 Air Analytical Method. Naphthalene IARS are included consistent with the analytical requirements outlined in Section 2.1(c) 3 of the *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E). As mandated by the *Brownfield and Contaminated Site Remediation Act* (N.J.S.A. 58:10B-1 et seq.), an incremental lifetime cancer risk of  $1 \times 10^{-6}$  and a Hazard Quotient (HQ) of 1 are used in the calculation of the standards. The IARS for the VI exposure pathway include both residential and nonresidential values. Pursuant to the *Remediation Standards* (N.J.A.C. 7:26D-5), the residential and nonresidential IARS shall be used as default standards for the VI exposure pathway. An Alternative Remediation Standard (ARS) for indoor air may be developed on a site-specific basis pursuant to N.J.A.C. 7:26D-8 and Appendix 9.

Compliance with the IARS and ARS for indoor, along with the evaluation of the VI exposure pathway using the associated vapor intrusion screening levels (VISL), follows those procedures outlined in applicable Departmental guidance/regulations including but not limited to: the *Vapor Intrusion Technical (VIT) Guidance* (Version 5.0), *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E), and the *Technical Guidance for the Attainment of Remediation Standards and Site-Specific Criteria*. The above Departmental guidance and regulations may be accessed at <http://www.state.nj.us/dep/srp/regs/> or <https://www.nj.gov/dep/srp/guidance/>. Contacts for technical questions regarding the IARS and the VI exposure pathway can be found at <http://www.nj.gov/dep/srp/guidance/vaporintrusion/vicontacts.htm>.

## 2. Methodology for Developing the Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway

### 2.1. Overview

The residential and nonresidential IARS for the VI exposure pathway represent the higher of the contaminants' indoor air human health-based criteria and the contaminants' analytical reporting limits (RL). The indoor air health-based criterion for each contaminant is determined as the more stringent of the cancer and non-cancer based value. Calculation of the indoor air human health-based criteria follows the risk-based air equations and input parameters presented in the USEPA Regional Screening Level (RSL) Tables that are consistent with USEPA's RAGS Part F (USEPA 2009).

The residential IARS address chronic inhalation of indoor air by building occupants under a residential exposure scenario. Pursuant to the *Remediation Standards*, the residential IARS are applicable to a residence, school and child care facility. The nonresidential IARS are based on chronic inhalation exposure to indoor air by the worker in a commercial/industrial setting. The USEPA recommended exposure parameters used in the development of the residential and nonresidential IARS are discussed in Section 2.4. The basis of the analytical RL used in the development of the standards is described in Section 3.2. While USEPA recommended equations and default parameters are used, some differences, as discussed below, are incorporated in the development of the standards to be consistent with current Departmental policy.

## 2.2. Equations

The risk-based equations and input parameters presented below are used in the development of the residential and nonresidential indoor air human health-based criteria. Carcinogenic and non-carcinogenic indoor air human health-based criteria are calculated for the listed contaminants under a residential and nonresidential exposure scenario when applicable toxicity information is available.

### Equation 1: Carcinogenic Effect Equation

$$IA_c = \frac{TR * AT * LT}{EF * ED * ET * \frac{1 \text{ day}}{24 \text{ hours}} * IUR}$$

### Equation 2: Non-carcinogenic Effect Equation

$$IA_{nc} = \frac{THQ * AT * ED * \frac{1000 \mu g}{mg}}{EF * ED * ET * \frac{1 \text{ day}}{24 \text{ hours}} * \frac{1}{RfC}}$$

Source: USEPA, Regional Screening Levels (RSLs) - Equations (November 2018)

Parameter	Description	Default
IA <sub>c</sub>	carcinogenic indoor air human health-based criterion	Chemical specific (µg/m <sup>3</sup> )
IA <sub>nc</sub>	non-carcinogenic indoor air human health-based criterion	Chemical specific (µg/m <sup>3</sup> )
IUR	inhalation unit risk, cancer effects	Chemical specific (µg/m <sup>3</sup> ) <sup>-1</sup>
RfC	inhalation reference concentration, non-cancer effects	Chemical specific (mg/m <sup>3</sup> )
TR	target cancer risk	1 x 10 <sup>-6</sup>
THQ	target hazard quotient	1
LT	lifetime, cancer effects	70 years
AT	averaging time, residential and nonresidential	365 days per year
ED	exposure duration, residential	26 years
	exposure duration, nonresidential	25 years
EF	exposure frequency, residential	350 days per year
	exposure frequency, nonresidential	250 days per year
ET	exposure time, residential	24 hours per day
	exposure time, nonresidential	8 hours per day

Exposure Parameters Source: USEPA, Memorandum: Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120.4-12. February. 2014.

### 2.2.1. Mutagenic Mode of Action

Some contaminants have been determined to have a mutagenic mode of action or early lifetime exposure component. Mutagenicity refers to the capacity to induce or increase the rate of genetic change. The USEPA RSLs and RAGS Part F recommend use of modified equations to address the possibility that exposures to these chemicals in early life may result in higher lifetime cancer risk than a comparable duration of adult exposure (USEPA, 2009). For the VI exposure pathway, the affected contaminants include methylene chloride, trichloroethene and vinyl chloride.

While the Department's Site Remediation and Waste Management Program (SRWMP) supports the protection against cancer risks from early-life exposure in the context of the baseline risk assessment and its associated screening levels, as existing policy, the SRWMP does not include the mutagenic mode of action in the development of its soil or indoor air remediation standards. By regulation, the Department's standards are based on a conservative 10<sup>-6</sup> risk level for carcinogenic compounds, which is protective of any additional risks incurred from early life exposure. The SRWMP will continue to review this issue as more information becomes available and may consider it for future amendments to the Remediation Standards, N.J.A.C. 7:26D.

### 2.3. Toxicity Factors

A variety of sources were evaluated to identify available carcinogenic and non-carcinogenic toxicity information for use in the development of the standards. Toxicity factors included in the calculation of the indoor air human health-based criteria follow the Department's inhalation remediation standards hierarchy, as much as possible. The inhalation toxicity factor hierarchy includes toxicity information obtained from the USEPA Integrated Risk Information System (IRIS) database as the Tier 1 preferred source of information. Tier II includes all other sources of inhalation toxicity factor information, such as the USEPA Provisional Peer Reviewed Toxicity Values (PPRTV), California Environmental Protection Agency (CalEPA), USEPA Health Effects Summary Tables (HEAST) and the Agency for Toxic Substance Disease Registry (ATSDR) database values. A breakdown of the toxicity factor sources used in the development of the IARS is presented below.

Tier	Toxicity Source	Carcinogenic-Inhalation Unit Risk (IUR)	Non-carcinogenic Reference Concentration (RfC)
I	IRIS	9	29
II	PPRTV	1	4
	CalEPA	3	0
	HEAST	0	1
	ATSDR	0	1

The toxicity factors used in the development of the indoor air human health-based criteria are consistent with those values used in the development of the soil remediation standards for the inhalation exposure pathway. Contaminant specific toxicity information and their sources are presented in **Table 1**.

While the toxicity information is evaluated and selected with a preference for following the hierarchy whenever possible, consideration is also given to the most recent information available and the use of best professional judgment. Deviations from the above hierarchy are discussed below.

#### 2.3.1. Route-to-Route Extrapolation

Inhalation toxicity factors have been developed for some contaminants using studies that relate health effects to oral exposure in the absence of sufficient inhalation studies. As stated in RAGS Part F, performing route-to-route extrapolation may be inappropriate when data from one route of exposure is substituted for another without consideration of the pharmacokinetic differences between the routes (USEPA, 2009).

Consequently, the Department decided not to do such extrapolation to develop standards without specific contaminant-based justification. As a result, toxicity factors based on route-to-route

extrapolation have been evaluated by the Department and their use restricted. Route-to-route extrapolation based toxicity factors are used when the values have been developed after a more extensive evaluation of the potential effects of route of exposure (such as through the use of Physiologically Based Pharmacokinetic (PPBK) modeling) in the generation of the toxicity values. Available toxicity factors that are not used by the Department in the generation of the IARS due to the use of route-to-route extrapolation that did not involve more extensive evaluation of the potential effects of route extrapolation are listed below.

<b>Tier</b>	<b>Toxicity Source</b>	<b>Inhalation Unit Risk (IUR)</b>	<b>Reference Concentration (RfC)</b>
I	IRIS	bromoform chloroform 1,2-dichloroethane hexachloro-1,3-butadiene 1,1,2-trichloroethane	
II	CalEPA	bromodichloromethane dibromochloromethane 1,4-dichlorobenzene 1,1-dichloroethane 1,1,2,2-tetrachloroethane	
II	NJDEP		tertiary butyl alcohol

### 2.3.2. Ethylbenzene

The existing IRIS toxicity assessment for ethylbenzene was last conducted in 1988 and does not include a cancer effects inhalation unit risk (IUR) factor (USEPA 1988). The IRIS toxicity assessment for ethylbenzene identifies the contaminant as a Class D carcinogen that is “not classifiable due to a lack of animal bioassays and human studies.” The IRIS assessment notes that the National Toxicology Program (NTP) has plans to initiate a 2-year carcinogenicity bioassay with additional metabolism and excretion studies to be conducted as well. Discussions with the USEPA indicate they had begun a reevaluation of the ethylbenzene IRIS toxicity assessment that was anticipated to take a number of years to complete; however, reassessment for the contaminant was suspended in 2018.

In 1999, the NTP published rat/mice inhalation studies for ethylbenzene, finding clear evidence of carcinogenic activity in male rats with increased incidence of renal tubule neoplasms (NTP, 1999). The NTP, through its studies, also found evidence of carcinogenic activity in female rats based on increased incidence of renal tubule adenomas. Evidence of carcinogenic activity was also found in 1) male mice based on increased incidence of alveolar/bronchiolar neoplasms; and 2) female mice based on increased incidence of hepatocellular neoplasms.

In 2007 (updated in 2009 and 2011) CalEPA adopted an ethylbenzene IUR based on the 1999 NTP studies (OEHHA 2011). The CalEPA IUR was developed using the renal tubule carcinoma or adenoma incidence data in male rats as the more reliable basis for estimating human cancer potency. The CalEPA assessment outlines in detail the evaluations (including PBPK modeling) conducted as part of the development of the IUR to address extrapolation of the toxicity data from animals to humans. Development of the IUR included public and peer review of the technical document outlining the basis of the value with approval by California's Scientific Review Panel for Toxic Air Contaminants. Documentation on the CalEPA IUR value may be accessed at <http://www.oehha.ca.gov/risk/ChemicalDB/index.asp>.

After consideration of the above information, including further evaluation of this issue by the Department's Division of Science, Research and Environmental Health, the Department used the CalEPA IUR toxicity information in its development of the IARS. This toxicity factor was used because the value was based on updated information (the 1999 NTP study) that was unavailable at the time of the IRIS assessment. The ethylbenzene CalEPA IUR is also included in the USEPA RSL tables and has been used by the Department in the VISL tables for the evaluation of the VI exposure pathway since March 2013.

#### **2.4. Exposure Parameters**

Exposure parameters recommended by the USEPA Superfund program (USEPA 2014) are used as input parameters for the calculation of the residential and nonresidential indoor air human health-based criteria. The input parameters reflect reasonable maximum exposure (RME) under the applicable exposure scenarios. USEPA defines the RME as the highest exposure that is reasonably expected to occur at a site (USEPA 1989). The residential exposure parameters include the presence of a resident in their home 24 hours/day, 350 days/year over a period of 26 years. The nonresidential exposure parameters consider an adult indoor worker in a commercial/industrial setting for 8 hours/day, 250 days/year for a total of 25 years. Consistent with USEPA, an averaging time (AT) of 365 days/year is used in the calculations with the inclusion of a lifetime (LT) of 70 years in the cancer equation since the risk is averaged over a 70 year lifetime. The exposure parameters, along with the applicable equations, are presented in Section 2.2 of this document.

#### **2.5. Group C Carcinogen Policy**

The Department has a policy for the development of remediation standards for contaminants classified as Group C carcinogens, which are defined as Possible Human Carcinogens by the USEPA under the 1986 guidelines, or Suggestive Carcinogens under the 2005 guidelines (USEPA 1986 and 2005). Group C carcinogen contaminants are contaminants for which some evidence of human carcinogenicity exists, but for which there is insufficient evidence to classify the contaminants as Known Human Carcinogens (Group A) or Probable Human Carcinogens (Group B). The Department uses this policy to develop Departmental health-based standards including remediation standards, drinking water health-based maximum contaminant levels, ground water quality criteria, and human health-based surface water quality criteria.

Under this Department policy, remediation standards for contaminants classified as Group C carcinogens under the 1986 guidelines or suggestive carcinogens under the 2005 guidelines that have carcinogenic toxicity information (IUR for the inhalation exposure pathway) are developed



as a carcinogen (Group A or B) using a target cancer risk of one excess human cancer in one million ( $1 \times 10^{-6}$  target cancer risk). For those contaminants that do not have available carcinogenic toxicity information, the Department developed a remediation standard using non-carcinogenic toxicity information (RfC for the inhalation exposure pathway), but the Department applied an added uncertainty factor of 10 to account for potential carcinogenic effects not addressed by the non-carcinogenic toxicity information.

As listed in **Table 1**, the Group C carcinogen policy is applicable to one contaminant, 1,1-dichloroethene, when developing the indoor air human health-based criteria. IRIS currently considers 1, 1-dichloroethene to be a “possible” human carcinogen (Group C carcinogen) or a contaminant that exhibits “suggestive evidence” of carcinogenicity by the inhalation route of exposure. Consistent with the Department’s Group C carcinogen policy, in the absence of a carcinogenic based toxicity factor, an additional uncertainty factor of 10 was applied to account for potential carcinogenic effects not addressed by the contaminant’s RfC.

## 2.6. Calculations

Carcinogenic and non-carcinogenic indoor air human health-based criteria for the residential and nonresidential exposure scenario are calculated for the listed contaminants following the above procedures, where applicable toxicity information is available (as presented in **Table 1**). The indoor air human health-based criteria are determined as the more stringent of the cancer or non-cancer based value.

In deriving the IARS for the vapor intrusion exposure pathway, the Department applied the rounding rules contained in the American Society for Testing and Materials (ASTM) Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications (ASTM E29-13). For example, in applying ASTM E29-13:

- If the first number beyond the second significant figure is *less than* five, then the second significant figure remains the same, while the remaining numbers are dropped. For example, if 4.438 is rounded to two significant figures, the result is 4.4.
- If the first number beyond the second significant figure is *greater than* five, then the second significant figure increases by one and the remaining numbers are dropped. For example, if 4.668 is rounded to two significant figures, the result is 4.7.
- If the first number beyond the second significant figure is five and there are other non-zero numbers beyond the five, then the second significant increases by one and the remaining numbers are dropped. For example, if 4.6534 is rounded to two significant figures, the result is 4.7
- If the first number beyond the second significant figure is five, and there are no numbers beyond this five (except zeros), then the second significant figure is rounded to the closest even number. For example, if 4.55 is rounded to two significant figures, then the result is 4.6; and when 4.65 is rounded to two significant figures, the result is also 4.6.

The resulting residential and nonresidential indoor air human health-based criteria are presented in **Tables 2 and 3**.

### **3. Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway**

#### **3.1. Determination of Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway**

The residential and nonresidential IARS for the VI exposure pathway are determined as the higher of the calculated indoor air human health-based criteria and the contaminants' analytical RL. The indoor air human health-based criteria default to the analytical RL when higher, since a contaminant's analytical RL is the lowest concentration reliably able to be detected by a laboratory using the applicable analytical method. The residential and nonresidential IARS, along with the indoor air human health-based criteria and the analytical RL, are presented in **Tables 2 and 3**.

#### **3.2. Air Analytical Reporting Limits**

In the Technical Requirements for Site Remediation (N.J.A.C. 7:26E), the analytical RL is defined as the "the sample equivalent concentration (i.e. based on sample specific preparation and analysis factors), for organics, associated with the lowest concentration standard used in the calibration of the method". The RL used in the development of the standards listed in **Tables 2 and 3** are based on the NJDEP-SRP Low Level USEPA TO-15 Method (NJDEP-LLTO-15 - 3/2007) March 2009 revision, Table 2.

Since the Department recommends use of NIOSH Method 6009 for the analysis of elemental mercury in indoor air, the NIOSH Method 6009 analytical RL is for use in the development of the elemental mercury IARS. NIOSH Method 6009 notes that the Limit of Detection for the method is 0.03 µg. The method further states that 2 to 100 L of air may be sampled. Based on this information, the theoretical RL could be 0.03 µg/100L or 0.3 µg/m<sup>3</sup>. Allowing for differences in sampling variability and recognizing a reporting limit of 0.3 µg/m<sup>3</sup> may be unrealistic at this time, the Department is requiring a reporting limit of 1 µg/m<sup>3</sup>. The above RL has been used in the development of the elemental mercury IARS.

### **4. Alternative Remediation Standards (ARS) for Indoor Air for the Vapor Intrusion Exposure Pathway**

Pursuant to the *Remediation Standards* (N.J.A.C. 7:26D-8 and Appendix 9), the Department will review proposals for an ARS for indoor air for the VI exposure pathway based on site-specific use of a property or area of concern (AOC) that affects indoor air exposure. This could include more restricted use of a site building resulting in less exposure to indoor air in the subject building. An ARS for indoor air may be developed for a nonresidential setting but is not applicable to a residence, school or child care center. Pursuant to N.J.A.C. 7:26D-8 and Appendix 9, Departmental approval is required prior to the use of an ARS for indoor air at a site or area of concern (AOC).

Information on the development and use of an ARS for indoor air may be found in Appendix G of the Department's *Vapor Intrusion Technical Guidance*, (Version 5.0) document located at <http://www.nj.gov/dep/srp/guidance/vaporintrusion/>. The Department has developed a calculator that includes the applicable risk-based equations and highlights the exposure parameters that may be adjusted in the generation of an ARS for indoor air for the VI exposure pathway. The calculator can be accessed at [NJDEP SRP - Guidance: Remediation Standards](#).

## **5. Interim Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway**

Interim IARS for the VI exposure pathway may be developed in the absence of available standards for contaminants of concern. The procedures outlined in this document, as applicable, are used to develop interim IARS provided appropriate toxicity information is available for the contaminants. Consistent with Subchapter 6 of the *Remediation Standards* (N.J.A.C.7:26D), the Department must approve all interim IARS prior to their use. Contacts for technical questions regarding the IARS and the VI exposure pathway can be found at <http://www.nj.gov/dep/srp/guidance/vaporintrusion/vicontacts.htm>.

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# Tables

**Table 1**  
**Indoor Air Toxicity Factors**

Contaminant	CAS No.	VI Recommendation	VI Toxicity Factor(s)
Acenaphthene	83-32-9	Not applicable	Not applicable
Acetone	67-64-1	No inhalation-based toxicity factors are available <sup>1</sup>	None
Acetophenone	98-86-2	Not applicable	Not applicable
Aldrin	309-00-2	Not applicable	Not applicable
Aluminum	7429-90-5	Not applicable	Not applicable
Anthracene	120-12-7	Not applicable	Not applicable
Antimony	7440-36-0	Not applicable	Not applicable
Arsenic	7440-38-2	Not applicable	Not applicable
Atrazine	1912-24-9	Not applicable	Not applicable
Barium	7440-39-3	Not applicable	Not applicable
Benzaldehyde	100-52-7	Not applicable	Not applicable
Benzene	71-43-2	IRIS IUR IRIS RfC	IRIS IUR (2000) 7.8E-06 (µg/m <sup>3</sup> )-1 IRIS RfC (2003) 3E-02 mg/m <sup>3</sup>
Benzo(a)anthracene	56-55-3	Not applicable	Not applicable
Benzo(a)pyrene	50-32-8	Not applicable	Not applicable
Benzo(b)fluoranthene	205-99-2	Not applicable	Not applicable
Benzo(k)fluoranthene	207-08-9	Not applicable	Not applicable
Beryllium	7440-41-7	Not applicable	Not applicable
1,1'-Biphenyl	92-52-4	Not applicable	Not applicable
Bis(2-chloroethoxy) methane	111-91-1	Not applicable	Not applicable
Bis(2-chloroethyl) ether	111-44-4	Not applicable	Not applicable
Bis(2-ethylhexyl) phthalate	117-81-7	Not applicable	Not applicable
Bromodichloromethane	75-27-4	No inhalation-based toxicity factors are available <sup>13</sup>	None
Bromoform	75-25-2	No inhalation-based toxicity factors are available <sup>13</sup>	None
Bromomethane	74-83-9	IRIS RfC	IRIS RfC (1992) 5E-03 mg/m <sup>3</sup>
2-Butanone	78-93-3	VI standard can be developed using IRIS RfC <sup>2</sup>	IRIS RfC (2003) 5E+00 mg/m <sup>3</sup>
Butylbenzylphthalate	85-68-7	Not applicable	Not applicable
Cadmium	7440-43-9	Not applicable	Not applicable
Caprolactam	105-60-2	Not applicable	Not applicable

Carbon disulfide	75-15-0	IRIS RfC	IRIS RfC (1995) 7E-01 mg/m3
Carbon tetrachloride	56-23-5	IRIS IUR IRIS RfC	IRIS IUR (2010) 6E-06 (µg/m3)-1 IRIS RfC (2010) 1E-01 mg/m3
Chlordane (alpha plus gamma mixture)	57-74-9	Not applicable	Not applicable
4-Chloroaniline	106-47-8	Not applicable	Not applicable
Chlorobenzene	108-90-7	PPRTV RfC	PPRTV RfC (2006) 5E-02 mg/m3
Chloroethane	75-00-3	IRIS RfC	IRIS RfC (1991) 1E+01 mg/m3
Chloroform	67-66-3	ATSDR RfC No other inhalation-based toxicity factors are available <sup>13</sup>	ATSDR RfC (2013) 9.8E-02 mg/m3
Chloromethane	74-87-3	IRIS RfC <sup>3</sup>	IRIS RfC (2001) 9E-02 mg/m3
2-Chloronaphthalene	91-58-7	Not applicable	Not applicable
2-Chlorophenol	95-57-8	Not applicable	Not applicable
Chrysene	218-01-9	Not applicable	Not applicable
Cobalt	7440-48-4	Not applicable	Not applicable
Copper	7440-50-8	Not applicable	Not applicable
Cyanide	57-12-5	Not applicable	Not applicable
Cyclohexane	110-82-7	IRIS RfC	IRIS RfC (2003) 6E+00 mg/m3
4,4'-DDD	72-54-8	Not applicable	Not applicable
4,4'-DDE	72-55-9	Not applicable	Not applicable
4,4'-DDT	50-29-3	Not applicable	Not applicable
Dibenz(a,h)anthracene	53-70-3	Not applicable	Not applicable
Dibromochloromethane	124-48-1	No inhalation-based toxicity factors are available <sup>13</sup>	None
1,2-Dibromo-3-chloropropane	96-12-8	Not applicable	None
1,2-Dibromoethane	106-93-4	IRIS IUR IRIS RfC	IRIS IUR (2004) 6E-04 (µg/m3)-1 IRIS RfC (2004) 9E-03 mg/m3
1,2-Dichlorobenzene	95-50-1	HEAST RfC	HEAST RfC (1997) 2E-01 mg/m3
1,3-Dichlorobenzene	541-73-1	No inhalation-based toxicity factors are available	None



1,4-Dichlorobenzene	106-46-7	IRIS RfC No other inhalation-based toxicity factors are available <sup>13</sup>	IRIS RfC (1996) 8E-01 mg/m <sup>3</sup>
3,3'-Dichlorobenzidine	91-94-1	Not applicable	Not applicable
Dichlorodifluoromethane	75-71-8	No inhalation-based toxicity factors are available <sup>4</sup>	None
1,1-Dichloroethane	75-34-3	No inhalation-based toxicity factors are available <sup>5</sup>	None
1,2-Dichloroethane	107-06-2	PPRTV RfC No other inhalation-based toxicity factors are available <sup>13</sup>	PPRTV RfC (2010) 7E-03 mg/m <sup>3</sup>
1,1-Dichloroethene	75-35-4	IRIS RfC with a Group C carcinogen factor	IRIS RfC (2002/2005) 2E-01 mg/m <sup>3</sup> Group C carcinogen factor 10
cis-1,2-Dichloroethene	156-59-2	No inhalation-based toxicity factors are available	None
trans-1,2-Dichloroethene	156-60-5	No inhalation-based toxicity factors are available <sup>6</sup>	None
2,4-Dichlorophenol	120-83-2	Not applicable	Not applicable
1,2-Dichloropropane	728-87-5	PPRTV IUR IRIS RfC	PPRTV IUR (2016) 3.7E-06 (µg/m <sup>3</sup> )-1 IRIS RfC (1991) 4E-03 mg/m <sup>3</sup>
1,3-Dichloropropene (cis and trans)	5422-75-6	IRIS IUR IRIS RfC	IRIS IUR (2000) 4E-06 (µg/m <sup>3</sup> )-1 IRIS RfC (2000) 2E-02 mg/m <sup>3</sup>
Dieldrin	60-57-1	Not applicable	Not applicable
Diethylphthalate	84-66-2	Not applicable	Not applicable
2,4-Dimethylphenol	105-67-9	Not applicable	Not applicable
Di-n-butylphthalate	84-74-2	Not applicable	Not applicable
2,4-Dinitrophenol	51-28-5	Not applicable	Not applicable
2,4-Dinitrotoluene /2,6-Dinitrotoluene (mixture)	25321-14-6	Not applicable	Not applicable
Di-n-octyl phthalate	117-84-0	Not applicable	Not applicable
1,4-Dioxane	123-91-1	IRIS IUR IRIS RfC	IRIS IUR (2013) 5.0E-06 (µg/m <sup>3</sup> )-1 IRIS RfC (2013) 3E-02 mg/m <sup>3</sup>
Endosulfan I and Endosulfan II (alpha and beta)	115-29-7	Not applicable	Not applicable
Endrin	72-20-8	Not applicable	Not applicable

Ethylbenzene	100-41-4	CalEPA IUR IRIS RfC	CalEPA IUR (2007) 2.5E-06 (µg/m <sup>3</sup> )-1 IRIS RfC (1991) 1E+00 mg/m <sup>3</sup>
Extractable Petroleum Hydrocarbons (EPH) (Category 1)	various	Not applicable	Not applicable
Extractable Petroleum Hydrocarbons (EPH) (Category 2)	various	Not applicable	Not applicable
Fluoranthene	206-44-0	Not applicable	Not applicable
Fluorene	86-73-7	Not applicable	Not applicable
alpha-HCH (alpha-BHC)	319-84-6	Not applicable	Not applicable
beta-HCH (beta-BHC)	319-85-7	Not applicable	Not applicable
Heptachlor	76-44-8	Not applicable	Not applicable
Heptachlor epoxide	1024-57-3	Not applicable	Not applicable
Hexachlorobenzene	118-74-1	Not applicable	Not applicable
Hexachloro-1,3-butadiene	87-68-3	No inhalation-based toxicity factors are available <sup>13</sup>	None
Hexachlorocyclopentadiene	77-47-4	Not applicable	Not applicable
Hexachloroethane	67-72-1	Not applicable	Not applicable
n-Hexane	110-54-3	IRIS RfC	IRIS RfC (2005) 7E-01 mg/m <sup>3</sup>
2-Hexanone	591-78-6	Not applicable	Not applicable
Indeno(1,2,3,-cd) pyrene	193-39-5	Not applicable	Not applicable
Isophorone	78-59-1	Not applicable	Not applicable
Isopropylbenzene	98-82-8	Not applicable	Not applicable
Lead	7439-92-1	Not applicable	Not applicable
Lindane (gamma-HCH) (gamma-BHC)	58-89-9	Not applicable	Not applicable
Manganese	7439-96-5	Not applicable	Not applicable
Mercury	7439-97-6	IRIS RfC	IRIS RfC (1995) 3E-04 mg/m <sup>3</sup>
Methoxychlor	72-43-5	Not applicable	Not applicable
Methyl acetate	79-20-9	No inhalation-based toxicity factors are available	None
Methylene chloride	75-09-2	IRIS IUR IRIS RfC	IRIS IUR (2011) 1E-8 (µg/m <sup>3</sup> )-1 IRIS RfC (2011) 6E-01 mg/m <sup>3</sup>
2-Methylnaphthalene	91-57-6	Not applicable	Not applicable
4-Methyl-2-pentanone	108-10-1	IRIS RfC	IRIS RfC (2003) 3E+0 mg/m <sup>3</sup>

2-Methylphenol	95-48-7	Not applicable	Not applicable
4-Methylphenol	106-44-5	Not applicable	Not applicable
Methyl tert-butyl ether (MTBE)	1634-04-4	IRIS RfC CalEPA IUR	CalEPA IUR (1999) 2.6E-07 (µg/m3)-1 IRIS RfC (1993) 3E+0 mg/m3
Naphthalene	91-20-3	CalEPA IUR IRIS RfC with a Group C carcinogen factor	CalEPA IUR (2004) 3.4E-05 (µg/m3)-1 IRIS RfC (1998) 3E-03 mg/m3 Group C carcinogen
Nickel	7440-02-0	Not applicable	Not applicable
4-Nitroaniline	100-01-6	Not applicable	Not applicable
Nitrobenzene	98-95-3	Not applicable	Not applicable
N-Nitroso-di-n propylamine	621-64-7	Not applicable	Not applicable
N-Nitrosodiphenylamine	86-30-6	Not applicable	Not applicable
2,2'-Oxybis(1-choloropropane)	108-60-1	Not applicable	Not applicable
Pentachlorophenol	87-86-5	Not applicable	Not applicable
Phenol	108-95-2	Not applicable	Not applicable
Polychlorinated biphenyls (PCBs)	1336-36-3	Not applicable	Not applicable
Pyrene	129-00-0	Not applicable	Not applicable
Selenium	7782-49-2	Not applicable	Not applicable
Silver	7440-22-4	Not applicable	Not applicable
Styrene	100-42-5	VI standard can be developed using IRIS RfC <sup>7</sup>	IRIS RfC (1993) 1E+0 mg/m3
Tertiary butyl alcohol (TBA)	75-65-0	No inhalation-based toxicity factors are available <sup>13</sup>	None
1,2,4,5-Tetrachlorobenzene	95-94-3	Not applicable	Not applicable
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	Not applicable	Not applicable
1,1,2,2-Tetrachloroethane	79-34-5	No inhalation-based toxicity factors are available <sup>13</sup>	None
Tetrachloroethene (PCE)	127-18-4	IRIS IUR IRIS RfC	IRIS IUR (2012) 2.6E-07 (µg/m3)-1 IRIS RfC (2012) 4E-02 mg/m3
2,3,4,6-Tetrachlorophenol	58-90-2	Not applicable	Not applicable
Toluene	108-88-3	IRIS RfC	IRIS RfC (2005) 5E+0 mg/m3
Toxaphene	8001-35-2	Not applicable	Not applicable

1,2,4-Trichlorobenzene	120-82-1	PPRTV RfC	PPRTV RfC (2009) 2E-03 mg/m3
1,1,1-Trichloroethane	71-55-6	IRIS RfC <sup>8</sup>	IRIS RfC (2007) 5E+0 mg/m3
1,1,2-Trichloroethane	79-00-5	No inhalation-based toxicity factors are available <sup>9</sup>	None
Trichloroethene (TCE)	79-01-6	IRIS IUR IRIS RfC <sup>10</sup>	IRIS IUR (2011) 4.1E-6 (µg/m3)-1 IRIS RfC (2011) 2E-3 mg/m3
Trichlorofluoromethane	75-69-4	No inhalation-based toxicity factors are available <sup>11</sup>	None
2,4,5-Trichlorophenol	95-95-4	Not applicable	Not applicable
2,4,6-Trichlorophenol	88-06-2	Not applicable	Not applicable
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	PPRTV RfC	PPRTV RfC (2016) 5E+00 mg/m3
1,2,4-Trimethylbenzene	95-63-6	IRIS RfC	IRIS RfC (2016) 6E-02 mg/m3
Vanadium	7440-62-2	Not applicable	Not applicable
Vinyl Chloride	75-01-4	IRIS IUR. IRIS RfC <sup>12</sup>	IRIS IUR (2000) 4.4E-6 (µg/m3)-1 IRIS RfC (2000) 1.E-1 mg/m3
Xylenes	1330-20-7	IRIS RfC	IRIS RfC (2003) 1.E-01 mg/m3
Zinc	7440-66-6	Not applicable	Not applicable

<sup>1</sup> An ATSDR RfC exists for acetone using the results of the Stewart 1975 study. The USEPA IRIS notes that this study should only be used in the development of a short-term exposure RfC and not a long term (chronic) exposure RfC.

<sup>2</sup> A NJDWQI RfC exists for 2-butanone, but the IRIS RfC has been determined by the Department to be more appropriate. The existing NJDWQI RfC is based on a route-to-route conversion of a NJDWQI RfD. The Department's Site Remediation and Waste Management Program policy does not allow, except where warranted, for the development of indoor air remediation standards based on route-to-route conversion of toxicity factors. This policy conforms with USEPA policy concerning route-to-route conversion of toxicity factors.

<sup>3</sup> A HEAST IUR exists for chloromethane, but a subsequent PPRTV review (2012) states that the use of the HEAST IUR is "Inadequate for an assessment of carcinogenic potential".

<sup>4</sup> A HEAST RfC and a PPRTV RfC exist for dichlorodifluoromethane. Both RfCs are derived using the same study (Prendergast 1967). The PPRTV is listed as an Appendix value. The PPRTV RfC is listed as an Appendix value because the Prendergast study was determined by USEPA to have flaws. It is the Department's Site Remediation and Waste Management Program policy not to use PPRTV Appendix values to develop remediation standards. As the HEAST RfC was developed using the Prendergast study data, the Department decided not to use this RfC in the development of a remediation standard.

<sup>5</sup> A HEAST RfC exists for 1,1-dichloroethane, but a subsequent PPRTV review (2006) indicated that data were inadequate to derive a chronic exposure RfC for 1,1-dichloroethane. A CalEPA IUR also exists for 1,1-dichloroethane but is based on a route-to-route conversion of an oral study. The Department's Site Remediation and Waste Management Program policy does not allow, except where warranted, for the development of indoor air remediation standards based on route-to-route conversion of toxicity factors.

<sup>6</sup> A PPRTV RfC exists for trans-1,2-dichloroethene but a subsequent IRIS assessment (2010) stated "the available inhalation data from the Freund study are insufficient to support reference value derivation and RfC."

<sup>7</sup> A HEAST 1991 IUR exists for styrene but USEPA NCEA does not recommend its use.

<sup>8</sup> Although an NJDWQI RfC exists for 1,1,1-trichloroethane, the Department determined that the IRIS RfC is a scientifically better toxicity value to develop a non-cancer-based soil inhalation remediation standard.

<sup>9</sup> Although a PPRTV RfC for 1,1,2-trichloroethane exists, it is listed as an Appendix value. The PPRTV Appendix value is based on a study that was determined by USEPA to have flaws. It is the Department's Site Remediation and Waste Management Program policy not to use PPRTV Appendix values to develop indoor air remediation standards. An IRIS IUR also exists for 1,1,2-trichloroethane but is based on a route-to-route conversion of an oral study. The Department's Site Remediation and Waste Management Program policy does not allow, except where warranted, for the development of indoor air remediation standards based on route-to-route conversion of toxicity factors.

<sup>10</sup> The IRIS RfC for trichloroethene is based on a route-to-route conversion of an ingestion study, which was determined to be acceptable by USEPA as substantiated by additional evaluation including physiologically-based pharmacokinetic modeling.

<sup>11</sup> A HEAST RfC exists for trichlorofluoromethane, but a subsequent PPRTV review (2009) indicated that data used to derive the RfC were inadequate.

<sup>12</sup> The IRIS RfC for vinyl chloride is based on a route-to-route conversion of an ingestion study, which was determined to be acceptable by USEPA as substantiated by additional evaluation including physiologically-based pharmacokinetic modeling.

<sup>13</sup> There is an inhalation toxicity factor available for this contaminant but it is based on a route-to-route conversion of an oral study. The Department's Site Remediation and Waste Management Program policy does not allow, except where warranted with physiologically-based pharmacokinetic modeling, for the development of indoor air remediation standards based on route-to-route conversion of toxicity factors.

## References

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NJDWQI (New Jersey Drinking Water Quality Institute). 1994. Maximum Contaminant Level Recommendation for Hazardous Contaminants in Drinking Water, Appendix A, Health-Based Maximum Contaminant Level Support Documents and Addenda. (A-280 Values). <https://www.state.nj.us/dep/watersupply/pdf/1994.pdf>

PPRTV (Provisional Peer Reviewed Toxicity Values for Superfund). United States Environmental Protection Agency. <http://hhpprtv.ornl.gov/index.html>

**Table 2**  
**Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway - Residential ( $\mu\text{g}/\text{m}^3$ ) (All numeric values are rounded to two significant figures)**

Contaminant	CAS No.	Carcinogenic Indoor Air Human Health-based Criterion	Noncarcinogenic Indoor Air Human Health-based Criterion	Reporting Limit	Indoor Air Remediation Standard Residential
Acetone	67-64-1	NA	NA	12	NA
Benzene	71-43-2	0.36	31	0.64	0.64 <sup>1</sup>
Bromodichloromethane	75-27-4	NA	NA	1.3	NA
Bromoform	75-25-2	NA	NA	2.1	NA
Bromomethane (Methyl bromide)	74-83-9	NA	5.2	0.78	5.2
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	NA	5,200	1.5	5,200
Carbon disulfide	75-15-0	NA	730	1.6	730
Carbon tetrachloride	56-23-5	0.47	100	1.3	1.3 <sup>1</sup>
Chlorobenzene	108-90-7	NA	52	0.92	52
Chloroethane (Ethyl chloride)	75-00-3	NA	10,000	1.3	10,000
Chloroform	67-66-3	NA	100	0.98	100
Chloromethane (Methyl chloride)	74-87-3	NA	94	1.0	94
Cyclohexane	110-82-7	NA	6,300	0.69	6,300
Dibromochloromethane	124-48-1	NA	NA	1.7	NA
1,2-Dibromoethane (Ethylene dibromide)	106-93-4	0.0047	9.4	1.5	1.5 <sup>1</sup>
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	NA	210	1.2	210
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	NA	830	1.2	830
Dichlorodifluoromethane (Freon 12)	75-71-8	NA	NA	2.5	NA
1,1-Dichloroethane	75-34-3	NA	NA	0.81	NA
1,2-Dichloroethane	107-06-2	NA	7.3	0.81	7.3
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	NA	21	0.79	21
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	NA	NA	0.79	NA
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	NA	NA	0.79	NA
1,2-Dichloropropane	78-87-5	0.76	4.2	0.92	0.92 <sup>1</sup>
1,3-Dichloropropene (total)	542-75-6	0.70	21	0.91	0.91 <sup>1</sup>
1,4-Dioxane	123-91-1	0.56	31	0.72	0.72 <sup>1</sup>

Ethylbenzene	100-41-4	1.1	1,000	0.87	1.1
Hexachlorobutadiene	87-68-3	NA	NA	2.1	NA
n-Hexane	110-54-3	NA	730	0.70	730
Mercury (elemental)	7439-97-6	NA	0.31	1.0	1.0 <sup>1</sup>
Methylene chloride (Dichloromethane)	75-09-2	280	630	1.7	280
4-Methyl-2-pentanone (MIBK)	108-10-1	NA	3,100	2.0	3,100
Methyl tert-butyl ether (MTBE)	1634-04-4	11	3,100	0.72	11
Naphthalene	91-20-3	0.083	3.1	2.6	2.6 <sup>1</sup>
Styrene	100-42-5	NA	1,000	0.85	1,000
1,1,2,2-Tetrachloroethane	79-34-5	NA	NA	1.4	NA
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	11	42	1.4	11
Toluene	108-88-3	NA	5,200	0.75	5,200
1,2,4-Trichlorobenzene	120-82-1	NA	2.1	3.7	3.7 <sup>1</sup>
1,1,1-Trichloroethane	71-55-6	NA	5,200	1.1	5,200
1,1,2-Trichloroethane	79-00-5	NA	NA	1.1	NA
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	0.68	2.1	1.1	1.1 <sup>1</sup>
Trichlorofluoromethane	75-69-4	NA	NA	1.1	NA
1,1,2-Trichloro-1,2,2- trifluoroethane (Freon TF)	76-13-1	NA	5,200	1.5	5,200
1,2,4-Trimethylbenzene	95-63-6	NA	63	0.98	63
Vinyl chloride	75-01-4	0.64	100	0.51	0.64
Xylenes (total)	1330-20-7	NA	100	0.87	100

NA – Not applicable because appropriate toxicological information is not available

<sup>1</sup> Standard set at reporting limit



**Table 3**  
**Indoor Air Remediation Standards for the Vapor Intrusion Exposure Pathway -**  
**Nonresidential ( $\mu\text{g}/\text{m}^3$ ) (All numeric values are rounded to two significant figures)**

Contaminant	CAS No.	Carcinogenic Indoor Air Human Health-based Criterion	Noncarcinogenic Indoor Air Human Health-based Criterion	Reporting Limit	Indoor Air Remediation Standard Nonresidential
Acetone	67-64-1	NA	NA	12	NA
Benzene	71-43-2	1.6	130	0.64	1.6
Bromodichloromethane	75-27-4	NA	NA	1.3	NA
Bromoform	75-25-2	NA	NA	2.1	NA
Bromomethane (Methyl bromide)	74-83-9	NA	22	0.78	22
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	NA	22,000	1.5	22,000
Carbon disulfide	75-15-0	NA	3,100	1.6	3,100
Carbon tetrachloride	56-23-5	2.0	440	1.3	2.0
Chlorobenzene	108-90-7	NA	220	0.92	220
Chloroethane (Ethyl chloride)	75-00-3	NA	44,000	1.3	44,000
Chloroform	67-66-3	NA	430	0.98	430
Chloromethane (Methyl chloride)	74-87-3	NA	390	1.0	390
Cyclohexane	110-82-7	NA	26,000	0.69	26,000
Dibromochloromethane	124-48-1	NA	NA	1.7	NA
1,2-Dibromoethane (Ethylene dibromide)	106-93-4	0.020	39	1.5	1.5 <sup>1</sup>
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	NA	880	1.2	880
1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	NA	3,500	1.2	3,500
Dichlorodifluoromethane (Freon 12)	75-71-8	NA	NA	2.5	NA
1,1-Dichloroethane	75-34-3	NA	NA	0.81	NA
1,2-Dichloroethane	107-06-2	NA	31	0.81	31
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	NA	88	0.79	88
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	NA	NA	0.79	NA
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	NA	NA	0.79	NA
1,2-Dichloropropane	78-87-5	3.3	18	0.92	3.3
1,3-Dichloropropene (total)	542-75-6	3.1	88	0.91	3.1
1,4-Dioxane	123-91-1	2.5	130	0.72	2.5

Ethylbenzene	100-41-4	4.9	4,400	0.87	4.9
Hexachlorobutadiene	87-68-3	NA	NA	2.1	NA
n-Hexane	110-54-3	NA	3,100	0.70	3,100
Mercury (elemental)	7439-97-6	NA	1.3	1.0	1.3
Methylene chloride (Dichloromethane)	75-09-2	1,200	2,600	1.7	1,200
4-Methyl-2-pentanone (MIBK)	108-10-1	NA	13,000	2.0	13,000
Methyl tert-butyl ether (MTBE)	1634-04-4	47	13,000	0.72	47
Naphthalene	91-20-3	0.36	13	2.6	2.6 <sup>1</sup>
Styrene	100-42-5	NA	4,400	0.85	4,400
1,1,2,2-Tetrachloroethane	79-34-5	NA	NA	1.4	NA
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	47	180	1.4	47
Toluene	108-88-3	NA	22,000	0.75	22,000
1,2,4-Trichlorobenzene	120-82-1	NA	8.8	3.7	8.8
1,1,1-Trichloroethane	71-55-6	NA	22,000	1.1	22,000
1,1,2-Trichloroethane	79-00-5	NA	NA	1.1	NA
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	3.0	8.8	1.1	3.0
Trichlorofluoromethane	75-69-4	NA	NA	1.1	NA
1,1,2-Trichloro-1,2,2- trifluoroethane (Freon TF)	76-13-1	NA	22,000	1.5	22,000
1,2,4-Trimethylbenzene	95-63-6	NA	260	0.98	260
Vinyl chloride	75-01-4	2.8	440	0.51	2.8
Xylenes (total)	1330-20-7	NA	440	0.87	440

NA – Not applicable because appropriate toxicological information is not available

<sup>1</sup> Standard set at reporting limit.