Intrusion Screening Values

Technical Support Document – January 2021

Intrusion Screening Values (ISVs) are chemical-specific, risk-based inhalation screening criteria for volatile compounds commonly evaluated during vapor intrusion investigations. An ISV is defined as a concentration of a contaminant in indoor air that is unlikely to harm human health. ISVs are used to screen out buildings unlikely to pose a health concern due to the vapor intrusion pathway, as well as determine when action may be needed to protect health.

The Minnesota Pollution Control Agency (MPCA) and the Minnesota Department of Health (MDH) cooperatively produced this technical support document.

The ISVs are located in a separate spreadsheet on the MPCA website.

I. ISV calculation

ISVs are calculated based on U.S. Environmental Protection Agency (EPA) Superfund risk assessment methodology (EPA, 2018a) and default parameters (EPA, 2014) that represent the highest exposure reasonably likely to occur. These exposure parameters are combined with toxicity values to calculate the ISVs. The following points are described in more detail in this document.

- Two ISVs--one to evaluate cancer risks and one to evaluate noncancer chronic risks--are derived when toxicity data are available. The lowest of either the cancer or noncancer ISV is selected as the final value.
- ISVs are calculated for a residential and a commercial/industrial exposure scenario.
- Expedited intrusion screening values (EISVs) are calculated to help determine when expedited action may be needed to protect health.
- Screening values for soil gas and sub-slab vapor results are calculated by applying an attenuation factor (33X ISVs, 33X EISVs).

A. Cancer and noncancer risk characterization

Cancer risks are characterized using an excess lifetime cancer risk, representing the incremental probability that an individual will develop cancer over a lifetime due to exposure to a carcinogen. Minnesota's long-standing public health policy is to derive values that limit excess cancer risk to 1 in 100,000 (10^{-5}) as a negligible, or acceptable, additional lifetime risk from exposure to carcinogens. The risk is a mathematical approximation of the likelihood of occurrence of cancer – it does not equate to actual increased cases of cancer. The true risk of cancer due to exposure to a chemical at an ISV could be zero.

Noncancer risks use a hazard quotient (HQ), the ratio of the exposure concentration over a concentration where no adverse health impacts are expected. An HQ of 1 means adverse noncancer effects are unlikely, and is used to derive the ISV. For HQs greater than 1, the potential for adverse effects increases, although by how much is unknown.

B. Toxicity values

As the equations below show, the ISV calculations for cancer are based on the inhalation unit risk (IUR) – the upper bound excess cancer risk from a continuous lifetime exposure to a chemical, which is derived from toxicological studies. For some chemicals, IURs were available, but were not used to calculate a cancer ISV due to professional judgment about the acceptability of the data, including considerations such as poor data quality, inappropriate route-to-route extrapolation, or weak evidence of carcinogenicity, etc.

In contrast, chronic reference concentrations (RfCs) are the basis of the noncancer ISVs calculations. The RfCs are also derived from toxicological studies and are defined by EPA as "an estimate, with uncertainty spanning perhaps an order of magnitude, of a continuous inhalation exposure to the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effects during a lifetime." MDH chose to use subchronic RfCs to calculate ISVs for three chemicals in the ISV spreadsheet (bromodichloromethane, chloroethane, and trichlorofluoromethane) because of the lack of acceptable chronic RfCs.

The sources of toxicity values used to develop the ISVs are MDH, EPA Integrated Risk Information System (IRIS), EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs), California Environmental Protection Agency, and the Agency for Toxic Substances and Disease Registry (ATSDR). MDH used professional judgment to select the highest quality toxicity values available. Selected toxicity values are expected to change over time with the addition of new MDH chemical reviews and other published values, which may result from additional study data or new data assessment methodologies. Toxicity values selected are included in the ISV spreadsheet. For chemicals that do not commonly drive risk decisions at vapor intrusion sites, it may be appropriate to request further consideration of toxicity values from MDH if they affect site decisions.

Incorporating early-life sensitivity for linear carcinogens

The EPA recommends combining age-dependent adjustment factors (ADAFs) with the cancer toxicity values to account for early-life susceptibility. EPA developed ADAFs of 10, 3, and 1 for the age groups of 0-2 years, 2-16 years, and 16-70 years, respectively (EPA, 2005).

MDH agrees that for many carcinogens, toxicity values calculated from adult animal studies or adult epidemiological studies underestimate lifetime exposure cancer risk. MDH applies EPA's ADAFs to linear carcinogens, unless study data sufficiently account for early-life susceptibility (see section on vinyl chloride below), or there is other chemical-specific information to determine that a different numerical adjustment should be made, or that no adjustment is appropriate (MDH, 2020). MDH reviewed the study data for the carcinogens and as a result has applied ADAFs to all of the carcinogenic residential ISVs.

C. Residential ISV equations and parameters

The residential scenario assumes people spend most, if not all, of the day at home for 26 years. This assumption is likely to be overprotective for most people. Equation #1 calculates the residential noncancer ISV.

$$Equation\ \#1\text{: }Residential\ noncancer\ ISV\ (\mu g/m^3) = \frac{HQ * RfC * AT}{ED * EF}$$

Parameter	Value	Description/Reference
HQ – Hazard Quotient	1	See "Cancer and Noncancer Risk Characterization" section above
RfC – Reference Concentration	Varies	See "Toxicity Values" section above
AT – Averaging Time	9,490 days	26 years*365 days
ED- Exposure Duration	26 years	90th percentile for current residence time (EPA, 2018; EPA, 2011, Table 16-108)
EF- Exposure Frequency	350 days	Away from home two weeks/year (EPA, 2018; EPA 1991, pg. 15)

Equation #2 calculates the residential cancer ISV, including age-dependent adjustment factors for early life sensitivity.

$$Equation\ 2\text{: } Residential\ Cancer\ ISV\ with\ ADAFs\ (\mu g/m^3) =$$

$$\frac{CR * AT}{IUR * [(EF * ED_{(0-2)} * ADAF_{(0-2)}) + (EF * ED_{(2-16)} * ADAF_{(2-16)}) + (EF * ED_{(16-26)} * ADAF_{(16-26)})]}$$

Parameter	Value	Description/Reference
CR – Cancer Risk Level	0.00001 (10^{-5})	MDH guidance for acceptable cancer risk of 1 excess cancer in 100,000 people exposed
AT – Averaging Time	25,550 days	70 years*365 days
IUR – Inhalation Unit Risk	Varies	See "Toxicity Values" section above
ED- Exposure Duration	26 years	90th percentile for current residence time (EPA, 2018; EPA, 2011, Table 16-108)
EF- Exposure Frequency	350 days	Away from home two weeks/year (EPA, 2018; EPA 1991, pg. 15)
$ED_{(0-2)}$ Exposure Duration	2 years	EPA, 2005; MDH, 2010
$ED_{(2-16)}$ Exposure Duration	14 years	EPA, 2005; MDH, 2010
$ED_{(16-26)}$ Exposure Duration	10 years	EPA, 2005; MDH, 2010
$ADAF_{(0-2)}$ Age-Dependent Adjustment Factor	10	EPA, 2005; MDH, 2010
$ADAF_{(2-16)}$ Age-Dependent Adjustment Factor	3	EPA, 2005; MDH, 2010
$ADAF_{(16-26)}$ Age-Dependent Adjustment Factor	1	EPA, 2005; MDH, 2010

D. Commercial/industrial ISV equations and parameters

The commercial/industrial (com/ind) scenario is based on adult workers exposed for ten hours a day, five days a week, for 50 weeks a year. Although EPA uses an exposure time of eight hours a day for this scenario, MDH recommends using ten hours to be protective of workers who are present in the workplace longer than eight hours a day. Equation #3 calculates the com/ind noncancer ISV, while Equation #4 calculates the com/ind cancer ISV.

$$Equation\ \#3\text{: } Commercial/Industrial\ Noncancer\ ISV\ \ (\mu g/m^3) = \frac{HQ * RfC * AT}{ED * EF * ET}$$

Parameter	Value	Description/Reference
HQ – Hazard Quotient	1	See "Cancer and Noncancer Risk Characterization" section above
RfC – Reference Concentration	Varies	See "Toxicity Values" section above
AT – Averaging Time	9,125 days	25 years*250 days
ED- Exposure Duration	25 years	95th percentile tenure with current employer (EPA, 2018; EPA, 1991 - citing Bureau of Labor Statistics, 1990)
EF- Exposure Frequency	250 days	5 days a week for 50 weeks (EPA, 2018; EPA, 1991)
ET – Exposure Time	10/24 hours	10 hours a day (MDH recommendation)

$$Equation\ \#4\text{: } Commercial/Industrial\ Cancer\ ISV\ \ (\mu g/m^3) = \frac{CR * AT}{IUR * ED * EF * ET}$$

Parameter	Value	Description/Reference
CR – Cancer Risk Level	0.00001 (10^{-5})	MDH guidance for acceptable cancer risk of 1 excess cancer in 100,000 people exposed
AT – Averaging Time	25,550 days	70 years*365 days
IUR – Inhalation Unit Risk	Varies	See "Toxicity Values" section above
ED- Exposure Duration	25 years	95th percentile tenure with current employer (EPA, 2018; EPA, 1991 - citing Bureau of Labor Statistics, 1990)
EF- Exposure Frequency	250 days	5 days a week for 50 weeks (EPA, 2018; EPA, 1991)
ET – Exposure Time	10/24 hours	10 hours a day (MDH recommendation)

E. Significant digits

ISVs are rounded to two significant figures. This level of precision is often not possible, since most toxicity values have one significant digit. Two significant digits are used for the ISVs to facilitate interpretation of the analytical data, which is typically reported with at least two significant digits. The EISVs, 33X ISVs, and 33X EISVs are all derived from ISVs calculated to two significant digits, which minimizes the effects on the values due to rounding.

F. Expedited ISVs (EISVs)

Expedited or EISVs are calculated using the same equations as the ISVs, except a cancer risk level (CR) of 1 in 10,000 (10^{-4}) or a noncancer hazard quotient (HQ) of three is used. The choice of the CR and HQ are policy decisions that mirror EPA's methodology for deriving their Regional Management Levels that support their decisions for removal actions (EPA, 2018b). Both cancer and noncancer EISVs are calculated and the final EISV is the lowest of either the cancer or noncancer EISV.

EISVs have been developed in order to help determine if expedited actions are needed to protect health. Exceedances of EISVs indicate an increased potential for exposure risk from vapor intrusion and it may be necessary to take a closer look at the situation, often in conjunction with MDH. Consult MPCA's program specific Best Management Practices for vapor intrusion to determine the need for expedited action.

Expedited action may be needed when TCE exceeds the ISVs rather than the EISVs (see TCE and Expedited Action below).

G. Sub-slab and soil gas screening values (33X ISV, 33X EISV)

The predicted amount of a contaminant in indoor air that may result from vapor intrusion is estimated using the concentrations in a sub-slab sample multiplied by an attenuation factor (AF).

An AF represents the reduction in vapor concentrations between a subsurface source and indoor air. MPCA uses EPA's recommended default attenuation factor for sub-slab and soil gas air of 0.03 (about 3% of the concentration in sub-slab soil vapor is expected in indoor air) (EPA, 2015). This is the 95th percentile of attenuation factors observed at twelve vapor intrusion sites located in eight states, which includes 431 paired residential sub-slab and indoor air samples. Although the amount of soil vapor that enters is different for every building, this default value should overestimate indoor air concentrations due to vapor intrusion in most situations.

Sub-slab and soil gas screening values (33X ISV, 33X EISV) are calculated by dividing the ISV or EISV by the attenuation factor as shown in equations #5 and #6 below.

$$Equation\ 5\text{: } 33X\ ISV = \frac{ISV}{0.03} \qquad\qquad Equation\ 6\text{: } 33X\ EISV = \frac{EISV}{0.03}$$

II. ISV Application

A. Determining when to use residential and commercial / industrial ISVs

ISVs are calculated for only residential and commercial/industrial scenarios. Site-specific ISVs or modifications to the ISVs are not used, due to the need for program consistency and the need to account for future changes in building occupancy. Both types of ISVs are protective of people considered to be sensitive, including women who are pregnant or may become pregnant, the elderly, and people living with chronic disease or a compromised immune system.

Residential ISVs are recommended for use if children are present for a significant amount of time and for long-term care, facilities (see table below). Applying residential values for situations with children is a long-standing practice in Minnesota, rooted in experiences with public acceptance. From a communication standpoint, public perception and acceptance can be important considerations when choosing whether to use residential or com/ind values where children and/or sensitive people are present. However, com/ind ISVs are expected to be protective of children visiting a location up to 4 hours/day for 5 days a week, with the exception of vinyl chloride (Note: the residential ISV for vinyl chloride should always be used in any scenario where children are expected to be present).

Type of ISV	Examples of exposures scenarios or settings
Residential	Any type of housing, long-term care facilities, schools, childcare centers, after-school programs, etc.
Commercial/Industrial	Restaurants, retail, hotels, churches, hospitals, health clinics, libraries, etc.

B. Workplaces that use contaminants of concern

The com/ind 33X ISVs are used to evaluate the vapor intrusion pathway in occupational settings, including at properties that use vapor intrusion contaminants of concern in the workplace. Mitigation decisions to address the vapor intrusion pathway are based on sub-slab concentrations. Mitigation may be needed at a property (despite the presence of an indoor air source of a subsurface contaminant) to address the added risk or future changes in chemical use or building occupancy. However, the ISVs do not replace applicable OSHA occupational standards. Note that MPCA and Minnesota OSHA have distinct legal responsibilities in identifying and minimizing environmental or workplace hazards.

C. Chemicals for which ISVs are not available

ISVs are not shown for several chemicals in the ISV spreadsheet because the data needed to derive a toxicity value is unavailable or is considered too poor by MDH or other agencies. If any of these contaminants are present in a soil gas plume at considerable quantities (using professional judgment) it may be appropriate to contact MDH to see if *any* data exists to help determine if there is a risk. For example, see contaminant–specific information below on dichlorodifluoromethane, a commonly detected contaminant that does not have an ISV.

III. Contaminant-specific information

A. Benzene

Benzene is a known human carcinogen and causes disruption of normal blood production. The basis of the benzene ISVs are the 2020 MDH Health-Based Values (HBVs) based on cancer and chronic non-cancer. MDH also developed acute, short-term, and subchronic HBVs for benzene (see table below for durations and concentrations). These shorter duration HBVs that are similar concentrations to the chronic HBV indicate that chronic exposure is not needed for benzene to affect the blood system.

The shorter duration HBVs increase the need to consider taking expedited action at concentrations above the EISVs, particularly for sensitive receptors or when there is greater likelihood of actual exposures. Taking action in a timely manner is intended to prevent health effects. Action is not considered urgent near the HBV concentrations in indoor air, because they are safe concentrations (not effect levels) with factors built into the calculation to ensure safety.

Duration	2020 HBV ($\mu g/m^3$)	Health Endpoint
Acute (24 hours or less)	30	blood system
Short-term (>24 hrs-30 days)	10	blood system
Subchronic (>30 days-~8 years)	8	blood system
Chronic (>~8 years-lifetime)	3	blood system
Cancer (lifetime)	0.8	leukemia

B. 1,3-Butadiene

1,3-Butadiene is a product of incomplete combustion of fossil fuels and biomass. It is also an industrial chemical used primarily in the production of polymers. 1,3-butadine is commonly detected in soil vapor samples at concentrations above ISVs or 33X ISVs and therefore have the potential to drive mitigation decision making. MPCA recognizes the difficulties of confirming or refuting a 1,3-butadine release as the compound rapidly degrades in air and is not commonly found in soil or groundwater due to its high reactivity. For sites where 1,3-butadine is detected in soil gas or sub-slab soil vapor, an evaluation of sampling techniques and potential sources should be conducted to help determine if the detections likely reflect cross-contamination from air emissions or an artifact of the sampling process, rather than a release of contaminants at the site.

C. Dichlorodifluoromethane

Dichlorodifluoromethane (DCDFM, or Freon 12), was widely used as a refrigerant and localized leak or spills appear relatively common. It is frequently found in soil vapor - occasionally in the hundreds of thousands of micrograms per cubic meter. There is no ISV (listed as “NA” or not available) because available data are not sufficient to develop a chronic toxicity value and evidence of health effects is lacking. Further investigation or mitigation of DCDFM detected in soil gas is usually not needed. MDH consultation may be warranted in cases where DCDFM is present in a widespread soil gas plume at extremely high concentrations (at least hundreds of thousands of $\mu g/m^3$) and there is evidence of indoor air exposure.

D. 1,2-Dichloroethane

1,2-Dichloroethane (1,2-DCA) is occasionally found in indoor air at concentrations above the ISVs. This solvent has received attention for potential vapor intrusion risk from its past use as an additive in leaded gasoline (along with 1,2-dibromoethane) to prevent buildup of lead deposits in engines. There have been studies that have investigated sources of 1,2-DCA in indoor air at vapor intrusion sites that have found evidence of indoor air sources (molded plastic products, PVC pipes, vinyl composite floor adhesive) and include discussion of other possible sources (Doucette, et al., 2009; Kurtz, et al., 2010). Indoor air sources may be considered a likely explanation when vapor intrusion as a source is in doubt. Health risk at concentrations just above the ISVs is considered low.

E. Methyl Ethyl Ketone (MEK)

In 2020, ATSDR published a new acute toxicity value (3,000 µg/m^3) that is lower the IRIS chronic value (5,000 µg/m^3). In the absence of a full air review of MEK, MDH reviewed the basis of both values and recommended the use of the ATSDR value. This acute duration ISV increases the need to consider taking expedited action at concentrations above the EISVs, particularly for sensitive receptors or when there is greater likelihood of actual exposures.

F. Trichloroethylene (TCE) and expedited action

Animal studies show TCE exposure in early pregnancy may increase the risk of certain heart defects to the developing fetus. TCE may also affect the developing immune system early in life. Because of these potential short-term effects, the threshold for evaluating the need for expedited action is exceedances of the ISV in indoor air samples and the 33X ISV in sub-slab samples (rather than the EISV and 33X EISV). Expedited action is needed if women who are pregnant or may become pregnant are occupants in a building affected by TCE vapor intrusion above these screening values. For more information on the application of the TCE values, please refer to the MPCA guidance document *Vapor investigation and mitigation decision best management practices (c-rem3-06e).*

G. Vinyl chloride

The vinyl chloride residential ISV is calculated using a unique equation provided by EPA to account for evidence in animal studies of increased sensitivity to vinyl chloride-induced carcinogenesis during early-life and prenatal exposures. Equation #7, shown below, adds early-life risk to later-life risk. EPA's Toxicological Review for Vinyl Chloride in IRIS explains this equation in section 5.3.5.1 (EPA, 2000).

$$Equation\ \#7.\ Vinyl\ Chloride\ residential\ cancer\ ISV\ \ (\mu g/m^3) = \frac{CR}{(IUR) + \frac{(IUR * EF * ED)}{AT}}$$

Due to the additional early life cancer risks to children, the vinyl chloride com/ind ISV is not reasonably protective of young children. The residential ISV should be used if children are expected to be present.

Vinyl chloride has not been identified as a common vapor intrusion risk driver at sites in Minnesota. This may be due to biodegradation of vinyl chloride in the vadose zone (EPA, 2015).

References

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