

Office of Environmental Health Hazard Assessment Comments on the Proposed Low-Threat UST Closure Policy, 7-14-11

The Office of Environmental Health Hazard Assessment (OEHHA) was requested by the State Water Resources Control Board (SWRCB) Underground Storage Tank Program to review the proposed Low-Threat UST Closure Policy, 7-14-11.

In reviewing this policy, OEHHA staff focused on the technical issues in the Technical Justification for Soil Screening Levels for Direct Contact and Outdoor Air Exposure Pathways and the Technical Justification for Low-Threat Closure Scenarios for Petroleum Vapor Intrusion Policy on the actual policy. The main focus was on whether the methodologies used to determine screening criteria are appropriate and health protective. In this regard, we concentrated on the toxicological and risk assessment aspects. While concentrating on these aspects we did note issues in the policy and technical discussions that we felt may impact on the assumptions used to develop the health based screening criteria. Any comments we made that concern the content and use of the policy are not meant to question or to disagree with the intent of the policy. We strongly support the role of the State Water Resources Control Board in developing policies that speed the closure and reduce the cost of the contaminated petroleum underground storage tank sites while protecting public and environmental health.

Primary Comments

Technical Justification for Soil Screening Levels for Direct Contact and Outdoor Air Exposure Pathways

This technical justification document provided a brief but straightforward discussion on how screening levels were derived. In general, the discussion on why specific methods and parameters were used was too limited. The choices made were not unreasonable, but should be justified over other standard methods and parameters. Some typographical errors were identified that can lead to confusion and a calculation error was identified that seems to be important to the final screening levels. Specific comments on this document are below.

1. Three indicator compounds were selected to characterize the total petroleum hydrocarbon (TPH) group – benzene, naphthalene, and PAHs. The reasons for their selection are not clearly stated. Other petroleum hydrocarbons having longer aerobic biodegradation half-lives (e.g., ethyl benzene vs. benzene) were not selected. Better explanation on the representativeness of the compounds selected is needed.
2. There should be an explanation provided on why the *American Society for Testing and Materials (ASTM)* methodology was used to determine volatilization factors (VF) instead of US EPA's method. In Table 6, the *Width of source area parallel to wind, or groundwater flow direction* needs more justification than ASTM 1996. An explanation should be provided about why this value is applicable for all sites. An

explanation should also be provided about the use of ASTM values for the parameters and not US EPA default values which are developed for specific parts of the state and size of the site.

3. The Soil Screening Levels values for naphthalene: residential; commercial/industrial; and utility workers in Table 9 are incorrect if one uses the stated *Organic carbon partition coefficient* and *Diffusion coefficient in air* of 1500 mL/g and 0.06 cm²/s, respectively, in Table 7. Actual *Organic carbon partition coefficient* and *Diffusion coefficient in air* used in the calculations were 1190 mL/g and 0.059 cm²/s, respectively. There should be a careful review comparing the listed parameters to the ones used in the calculations.
4. The introduction on page 2 states, *“The volatilization algorithm commonly used in USEPA screening level equations can greatly overestimate the amount of contaminant volatilizing into outdoor air for volatile chemicals (OEHHA, 2005).”* OEHHA did not make such a statement in the referenced document. This reference to OEHHA should be removed.
5. Fig. 1. Conceptual Site Model should include Inhalation of Particles under Exposure Routes for Subsurface Soil. This pathway should be marked as complete for the Trench/Utility Worker Scenario.
6. In paragraph 3 of page 2 it is stated, *“The toxicity value used for the entire group of carcinogenic hydrocarbons is California’s Office of Environmental Health Hazard Assessment (OEHHA) cancer potency value for benzo(a)pyrene.”* It would have been preferable to use Potency Equivalence Factors for PAHs, This is where the cancer potency is assigned to individual PAHs based on their potency relative to benzo(a)pyrene. A list of Potency Equivalency Factors PAHs has been developed by OEHHA (1993). Applying only the BAP potency value to the groups of PAHs overstates the risk, and is more health conservative. If you have done it that way for simplicity perhaps that should be mentioned in the document.
7. On page 4, in paragraph 2 it is stated that, *“For the residential exposure scenario, it is assumed that the receptor is a child for 6 years and then an adult for 24 years. When calculating carcinogenic risk, the total intake of a chemical over a lifetime is used; therefore, the carcinogenic residential screening levels are protective of the combined child plus adult scenario.”* This method has been commonly used. However, there is concern that children may be more sensitive than adults are to carcinogens. The U.S. Environmental Protection Agency has developed a methodology to formally account for this in assessing risk and so has OEHHA. OEHHA published its guidance in 2009 and we suggest that this be considered for use in developing the direct contact soil levels.
8. In paragraph 4, on page 4 it is stated that, *“...the exposure duration is assumed to be much shorter than in the other two scenarios; however, the chemical intake per*

day may be higher due to increased incidental ingestion.” The possibility that daily intake through inhalation would also be increased could also be considered.

9. Starting in the last paragraph on page 4 there is a discussion of a rare case of residential exposure from excavation of soil for a swimming pool. It provides assumptions that will lower exposures but does not discuss how exposures can greatly increase for a short period of time. The rare case of exposure should be discussed, but perhaps a specific example is not needed.

10. Specific errors or omissions

10.1. The $VF_{\text{subsurface}}$ equation was not provided in Table 5 with the other VF equations. In addition, the $VF_{\text{subsurface}}$ calculated values did not include the 1000x conversion factor so they are all too small and lead to Soil Screening Levels that are too large in Table 9.

10.2. In Table 1, the equation for $\ln F_{\text{adj}}$ contains an extra factor, AF_a , which does not belong there.

10.3. In Table 6, the variable symbol for *Outdoor air mixing zone height* should be “ δ_{air} ” and that for *Thickness of impacted soil* should be “d” so they are consistent with the equations.

10.4. In Tables 8 and 9 the value for “PAH” at “5 to 10” and “Utility,” respectively, is 7.5 mg/kg. This is different than the calculated value of 8 mg/kg.

10.5. In the last paragraph on page 5 at the end of the second sentence the phrase, “as shown in figure 2,” should be added.

Technical Justification for Low-Threat Closure Scenarios for Petroleum Vapor Intrusion Pathway

This technical justification document provides an overview of the reasons why bioattenuation of petroleum hydrocarbons allows for closure of the low-threat UST sites. The primary problems found in this discussion are that the important literature cited in the text does not appear to have gone through a peer review process and methods or reasons for choosing the ultimate criteria for the policy were not provided. Specific comments are provided below.

1. The last paragraph in the Executive Summary on page 2 states, “*The screening criteria may therefore not be applicable for non-retail (e.g., pipeline, manufacturing, and terminal) sites where significantly larger volume petroleum hydrocarbon releases may have occurred...*” It is suggested that the conditions making the policy non-applicable should be better described to avoid misinterpretation and misuse

(e.g., how large volume release is expected to prohibit the potential aerobic degradation).

2. The technical justification should more clearly state the difference between “high” (LNAPL) and “low” (dissolved-phase) concentration sources. The descriptions provided can be confusing.

For example on page 2 for groundwater, it indicates that benzene <15 mg/L is in dissolved phase, while on page 3 it indicates that benzene >3 mg/L is LNAPL. In addition, on page 5 it states, “A 10 mg/L benzene vapor source is consistent with a dissolved-phase source of benzene (or BTEX) of around 40 mg/L assuming equilibrium partitioning between soil-gas and groundwater and a Henry’s Law coefficient of 0.25 for benzene (or BTEX).” The above statements are contradictory. For example, benzene at 10 mg/L in groundwater cannot be present in dissolved phase and as LNAPL at the same time.

3. The technical justification requires more detailed information to make this policy transparent and to avoid misinterpretation and misuse. The screening criteria derivation, all assumptions, and the rationale should be provided to make this policy transparent.

This technical justification presents screening criteria for the indoor inhalation of petroleum vapors migrating from the subsurface pathway. It refers to the results and conclusions of certain modeling simulations (Abreu et al. 2009), and on the conclusions resulting from statistical treatment of field data. The screening criteria derivation is not provided in sufficient detail. Although the rationale relied on statements in the referenced sources, the derivation of the selected screening criteria values, e.g., for TPH concentration in bioattenuation zone, O₂ concentrations, exclusion distances, and attenuation factor under scenario 4, is not clear. This creates difficulties in the interpretation of the screening criteria and potentially in the use of this policy.

- 3.1. The document should clearly state the O₂ levels that permit aerobic biodegradation (characterizing “no bioattenuation” vs. “bioattenuation zone”); how they were “normalized” (Abreu et al., 2009); how they correspond to the aerobic half-life degradation rates; and the basis for 4% O₂ content as a point of departure for different criteria under Scenarios 3 and 4. The sub-scenario (Scenario 3) title should omit “without oxygen measurements” part because aerobic biodegradation cannot be expected to always occur.

Technical Background, Low Concentration Sources. The aerobic biodegradation is represented by the measurements of O₂ content in the subsurface soil and groundwater. The document does not provide the basis for 4% O₂ content as a point of departure for different criteria under Scenarios 3 and 4. Model studies described in section 3.1.1, on page 5, assume an average aerobic degradation half-life rate of 0.79 hr⁻¹. Further, the text states, “Note,

while a degradation rate of 0.75 hr^{-1} may seem high, the model only allows degradation in the regions where there is enough O_2 to support it. The model cutoff for allowing degradation was 1% O_2 ." One of the sub-scenarios under Scenario 3 lists the requirements for "Bioattenuation Zone Without Oxygen Measurements or Oxygen < 4 %". This title implies that the existence of some level of aerobic degradation in the exclusion zone (Figure 4 shows modeling based on significant degradation even at O_2 levels lower than 1 %). However, Scenario 4 assumes "No Bioattenuation Zone" when the O_2 content is below 4% at the bottom of the 5 foot exclusion distance. While these assumptions are contradictory, it is clear that a "bioattenuation" zone providing adequate biodegradation should not be assumed to always exist. Therefore, it is important to describe:

- The relationship between % O_2 content and biodegradation half-life rate, and all assumptions made;
- O_2 levels characterizing "no bioattenuation" vs. "bioattenuation zone";
- The basis for proposing different screening criteria below and above 4% O_2 should be supported by field data;
- The measurement of the O_2 content should be required under all scenarios.

3.2. According to the text and note 6, on page 8, benzene (an index chemical for TPHs) will be bioattenuated to $100 \mu\text{g}/\text{m}^3$, if the benzene source (in groundwater) is in concentration "from 0.1 mg/L to 15 mg/L", and is located 5 ft below the the foundation. This soil-gas "screening" concentration of $100 \mu\text{g}/\text{m}^3$ is considered "relatively conservative" based on an indoor air risk-based concentration of $2 \mu\text{g}/\text{m}^3$ (the authors apply a slab attenuation factor of 0.02). In Appendix 3, Scenario 3, Figure A presents a sub-scenario apparently based on the above field data analysis, namely screening criteria for exclusion distance of 5 feet between groundwater containing benzene at concentration <100 $\mu\text{g}/\text{L}$ (0.1 mg/L). It should be noted that the cancer risk of inhaling $2 \mu\text{g}/\text{m}^3$ of benzene under a residential scenario (30 years of exposure) is $2.4\text{E}-05$. While the acceptability of a specific risk level is a risk management decision to be made by the SWRCB, the typical acceptable *de minimis* target cancer risk is $1.0\text{E}-06$. Therefore, the expected bioattenuated concentration of $100 \mu\text{g}/\text{m}^3$ ($2 \mu\text{g}/\text{m}^3$ indoors) should not be referred to as conservative. Additional discussion might be applicable to indicate why this residential exposure level is acceptable.

3.3. Sub-scenarios B and C are based on modeling simulations (and perhaps on the field data commented above under sub-scenario A), and require additional detail to support the proposed combinations of exclusion distances, benzene groundwater concentrations, soil TPH concentrations, and O_2 content.

3.4. Scenario 4 allows for applying a 1,000-fold factor to the benzene CHHSL values if the O_2 concentration at the bottom of the 5 foot exclusion distance is $\geq 4 \%$. According to Section 4.4 (pages 21-22), the screening criteria are based on the same modeling study (Abreu et al., 2009). The text states that "the proposed

vapor screening criteria of $5,000 \mu\text{g}/\text{m}^3$ is very conservative”, and that the 4% O_2 requirement “is a very conservative level for biodegradation to occur.” The text should clarify the basis for these conclusions. The proposed 1,000-fold factor should, if possible, be verified by field data.

3.5. Scenarios 3 and 4. The rationale for the screening criterion for Total TPH in bioattenuation zone soil to “contain Total TPH (TPH_g and TPH_d combined) less than $100 \text{ mg}/\text{kg}$ throughout the entire depth of the attenuation zone” should be provided. The only text related to this soil concentration level appears on page 3 (note 2), and on page 4 and states that “ $<100 \text{ mg}/\text{kg}$ is a good indication that there is a small or low concentration VOC source.” References to support this statement could be given, for example modeling or field data showing that this soil contamination will not affect the aerobic biodegradation of the vapors coming from the source located underneath (groundwater or soil).

3.6. The calculations on page 7, converting vapor phase concentrations, appear to be incorrect and should be double-checked.

On page 7 it states, “The analyses indicate that “dissolved-phase” sources $<6 \text{ mg}/\text{L}$ benzene in groundwater (or $\sim 24,000,000 \mu\text{g}/\text{m}^3$ vapor phase equivalent⁵) are completely attenuated within distances of 5 ft. or less.” Footnote 5 states, “Assuming a Henry’s Law coefficient of $0.25 \text{ cm}^3/\text{cm}^3$ for benzene.” The vapor concentration at the groundwater source (assuming equilibrium) should be calculated as the product of the groundwater concentration and the Henry’s Law coefficient (User’s Guide for Evaluating Subsurface Vapor Intrusion into Buildings, US EPA, 2004). Accordingly, “ $\sim 24,000,000 \mu\text{g}/\text{m}^3$ ” should probably read $1,500,000 \mu\text{g}/\text{m}^3$. Similarly, “ $7,500,000 \mu\text{g}/\text{m}^3$ ” should probably read $3,750,000 \mu\text{g}/\text{m}^3$ in footnote 6, on page 8.

4. References provided:

4.1. The main article describing the modeling is cited under two separate publications – Abreu et al., 2009 and API, 2009. These publications appear to contain the same information by the same authors so only one should be cited.

4.2. The reference cited as what seems to be the primary source for much of the technical justification is Lahvis, 2011. This citation is not an article but a presentation to the Ministry of the Environment of British Columbia which was not available for review. The presentation was based on Davis, 2009 – article which seems to not have been peer-reviewed (LUSTLine Bulletin), and based in turn on the author’s own database which is not publicly available. Other cited articles (DeVaull) are in press. The most important references used to support the methodology being used for the policy should come from peer reviewed literature. If this is not possible, there needs to be a discussion on why this information can be relied on to develop the methodology on which to base the policy.

- 4.3. The text refers to a non-existing guidance document, e.g., page 2 *“The materials referenced in this technical justification are consistent with the technical material being used to develop guidance by US EPA’s Office of Underground Storage Tanks (OUST)’s Task Force on Petroleum Vapor Intrusion.”* While US EPA may be developing such a document, it should not yet be cited.
- 4.4. The reference list is not consistent with the text. The list shows sources which are not cited in the text, e.g., Abreu et al., 2006; ITRC, 2007; Lahvis et al. 2010; Lahvis et al, 1999, Lahvis et al. 1996; McHugh et al., 2010; Potter et al., 1998. The text cites a reference not shown in the reference list - TPHCWG, 1998.
5. Minor errors or inconsistencies
- 5.1. In paragraph 2 on page 1 the part that states, *“(Note the CHHSL for benzene in soil gas is $83 \mu\text{g}/\text{m}^3$.)”* should read: *“(Note the **residential** CHHSL for benzene in soil gas, without engineered fill under the foundation, is $36 \mu\text{g}/\text{m}^3$ and for **commercial**, without engineered fill under the foundation, is $120 \mu\text{g}/\text{m}^3$.)”* or *“(Note the **residential** CHHSL for benzene in soil gas, with engineered fill under the foundation, is $85 \mu\text{g}/\text{m}^3$ and for **commercial**, with engineered fill under the foundation, is $280 \mu\text{g}/\text{m}^3$.)”* The correct CHHSLs to cite depend on your scenario. Newer construction would likely have engineered fill under the foundation, while older construction may not.
- 5.2. On page 5 in paragraph 1, the sentence, *“Note, while a degradation rate of 0.75 hr^{-1} may seem high, the model only allows degradation in the regions where there is enough O_2 to support it,”* should probably have the degradation rate listed as **0.79 hr^{-1}** since this is the rate used throughout the document.
- 5.3. Also on page 5 in paragraph 1, the statement, *“A $10 \text{ mg}/\text{L}$ benzene vapor source is consistent with a dissolved-phase source of benzene (or BTEX) of around $40 \text{ mg}/\text{L}$ assuming equilibrium partitioning between soil gas and groundwater and a Henry’s law coefficient of 0.25 for benzene (or BTEX).”* has a different Henry’s law coefficient than is given in Table 7 of the *“Technical Justification for Soil Screening Levels for Direct Contact and Outdoor Air Exposure Pathways”* where the Henry’s law constant is listed as 0.23.
- 5.4. In paragraph 2 on page 9, there are two sentences that say, *“In summary, field data from retail sites shows that for low concentration (e.g., dissolved-phase only) sources, benzene will be attenuated to below screening levels within 5 ft above the water table. Vapor intrusion risks would be rare to non-existent at these retail sites provided the water table does not come in contact with the building foundation.”* This could be rewritten to be clearer. A suggestion is, *“In summary, field data from retail sites **analyzed by Lahvis (2011)** show that for low concentration (e.g., dissolved-phase only) sources, benzene will be attenuated to below screening levels (**$100 \mu\text{g}/\text{m}^3$**) within 5 ft above the water*

table. Vapor intrusion risks would be **low** at these retail sites provided the water table does not **rise above 5ft below the building foundation**.”

Supplementary Comments

While reviewing the policy and technical justifications a number of questions came up that had to do with how well the site must be characterized before this policy can be followed. There are portions of the policy that suggest that the sites need to be well characterized before a low-threat closure can be done. However, there are no specific requirements provided, which raises concerns about how users will interpret the policy. In discussions with the SWRCB staff, we were told that this policy cannot be used until the site is fully characterized in a manner similar to the requirements of the LUFT Manual. We feel this should be more explicitly indicated in the policy. The following comments were developed based on our initial review and are included here to highlight our questions that arose based on our lack of understanding and that we feel will also occur with users of the policy.

Low-Threat UST Closure Policy 7-14-11

1. On page 2, the policy states, “... *if a particular site with a different release scenario exhibits attributes similar to those which this policy addresses, the criteria for closure evaluation of these non-UST sites should be similar to those in this policy.*” This needs clarification and a list of the attributes to prevent misinterpretation and misuse.
2. On page 3, the policy provides “*General Criteria*” that must be satisfied by all candidate sites. It then expands on these criteria, one of which is: b. The unauthorized release consists only of petroleum. The expanded description of this criterion states, “*For the purposes of this policy, petroleum is defined as crude oil, or any fraction thereof, which is liquid at standard conditions of temperature and pressure, ..., including any additives and blending agents such as oxygenates contained in the formulation of the substances.*” Some additives may not biodegrade. Therefore, it is incorrect to imply that any additive or blending agents will biodegrade to the same level as the selected representative petroleum compounds (benzene, naphthalene, and PAHs for direct contact; benzene for vapor intrusion). There should be some method to determine if any additive or blending agents may pose a hazard after the petroleum biodegrades.
3. Clarification or revision of the text is needed on page 7 to the last paragraph in the section,
“2. *Petroleum Vapor Intrusion to Indoor Air*”
“*Exception: Exposures to petroleum vapors associated with historical fuel*”

system releases are comparatively insignificant relative to exposures from small surface spills and fugitive vapor releases that typically occur at active fueling facilities. Therefore, satisfaction of the media-specific criteria for petroleum vapor intrusion to indoor air is not required at active commercial petroleum fueling facilities, except in cases where release characteristics can be reasonably believed to pose an unacceptable health risk.”

The text implies that small surface spills and fugitive vapor releases that typically occur at active fueling facilities are more significant than the historical fuel system releases and states there is no need for satisfaction of the media-specific criteria for petroleum vapor intrusion to indoor air at the active commercial petroleum fueling facilities from the historical fuel system releases. If this site is then given a uniformed closure letter, when will the site be re-evaluated if the retail property becomes a residential property?

4. The text on page 9, “*b. Monitoring Well Destruction*” seems to be in conflict with “*Resolution No. 92-49*” discussed on page 8.

On page 9, revision or clarification is needed to the first paragraph, “*b. Monitoring Well Destruction – All wells and borings installed for the purpose of investigating, remediating, or monitoring the unauthorized release shall be properly destroyed prior to case closure unless a property owner certifies that they will keep and maintain the wells or borings in accordance with applicable local or state requirements.*” This requirement seems to be in conflict with “*Resolution No. 92-49 does not require that the requisite level of water quality be met at the time of case closure; it specifies compliance with cleanup goals and objectives within a reasonable time frame.*” How would the levels of benzene and MTBE in groundwater (required under site classes 2 and 4, on page 6) be monitored if the monitoring wells are destroyed when the site closure is implemented under the assumption of compliance with goals/objectives within a reasonable time frame?

5. The policy does not state and should clearly state when it should not be applied, e.g., the mixed releases of petroleum and other contaminants; non-retail sites (pipelines, refineries), etc. (For additional conditions please refer to the comments in the Vapor Intrusion section below.)

Technical Justification for Low-Threat Closure Scenarios for Petroleum Vapor Intrusion Pathway

The following comments were prepared because the policy was not clear that a full site investigation and characterization is required before this policy is applicable to the site closure. If the sites must first go through a full site investigation and characterization, these comments may not be useful.

1. If such conditions resulting in vapor intrusion exist, the site should be evaluated following a site-specific assessment approach. The site and the impacted off-site areas should be investigated to eliminate such conditions. Examples of such prohibitive conditions include:
 - 1.1. Seasonal groundwater fluctuations may move the contamination up into the exclusion zone (requires multiple groundwater elevation measurements);
 - 1.2. Presence of preferential pathways: gas stations are a special case since tanks are backfilled with clean gravel which provides no habitat for microorganisms and easy migration into the gas-station building;
 - 1.3. Presence of perched zones under the building which hold LNAPL or dissolved phase petroleum hydrocarbons close to the building foundation;
 - 1.4. Presence of dewatering pump with sump bringing contaminated water or vapors inside the building;
 - 1.5. Large building foundation and or pavement (typically installed on gravel) around the building may result in anoxic soil conditions;
 - 1.6. Presence of highly organic soils, e.g. peat may increase the O₂ demand to degrade its organic content thus limiting the petroleum hydrocarbons' degradation (requires measurement of the fraction of organic carbon);
 - 1.7. Clay soils have lower air permeability resulting in lower O₂ content and poorer aerobic conditions/degradation;
 - 1.8. The presence of methane should be analyzed for. Methane may be formed as a result of anaerobic degradation of petroleum hydrocarbons. It occurs more often at high volume concentrated (LNAPL) releases or where ethanol-blended gasoline has been released where the O₂ is exhausted. It may cause increases in the gas volume and gas pressure and move the petroleum hydrocarbon vapors towards the surface. It is degraded in aerobic conditions thus additionally decreasing the available O₂. Methan may cause an explosion in confined spaces.
2. All necessary sampling procedures and analytical methods (used to quantify the screening criteria and to investigate prohibitive conditions such as the ones described above) should be described or referred to in regulatory guidance documents.

The policy should recommend procedures or refer to guidance documents describing sampling (e.g., number and location of samples) and analytical methods for the recommended screening criteria. The DTSC Guidance for the Evaluation

and Mitigation, 2004 should be followed to check for acute indoor hazards, and for preferential pathways. Methane should also be analyzed for. The policy should consider and describe conditions requiring confirmation sampling (e.g., under building foundations) to ensure the concentrations under the potentially impacted building are or will result in insignificant risk.

3. The policy should recommend a procedure demonstrating that the site-specific aerobic degradation attenuates the petroleum vapors to levels resulting in insignificant cancer risk and non-cancer hazard levels.

The aerobic biodegradation depends on the availability of microorganisms in sufficient quantities to support the biodegradation process, and sufficient soil O₂ and water to create their habitat. The application of this policy should be contingent upon demonstrating that the site-specific aerobic degradation attenuates the petroleum hydrocarbons to levels resulting in insignificant cancer risk and non-cancer hazard levels. One way to do this is to collect on-site samples, e.g. in depth to prepare vertical concentration profiles for O₂, VOCs, and CO₂.

References cited by OEHHA.

Office of Environmental Health Hazard Assessment (OEHHA) 1993. Benzo[a]pyrene as a Toxic Air Contaminant. Part B. Health Effects of Benzo[a]pyrene. Air Toxicology and Epidemiology Section, Berkeley, CA.

Office of Environmental Health Hazard Assessment (OEHHA) 2009. Technical Support Document for Cancer Potency Factors: Methodologies for derivation, listing of available values, and adjustments to allow for early life stage exposures. Air Toxicology and Epidemiology Branch. Oakland, CA.

US Environmental Protection Agency (US EPA) 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. Office of Emergency and Remedial Response. Washington , DC.