ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION
DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES REMEDIATION PROGRAM

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Inhalation of Diesel Vapor in Indoor Air

The science of evaluating the complex indoor air pathway is evolving. The following Ecology and Environment, Inc memo summarizes the different and sometime divergent approaches taken by the federal and state governments to evaluate the pathway. Alaska Department of Environmental Conservation is presently developing a policy for the evaluation of the indoor air pathway that is appropriate for conditions in Alaska. In the absence of such guidance and for consistency within the Contaminated Sites program, project managers should consult with their supervisors on when and how to evaluate the pathway.

1. Introduction

Ecology and Environment, Inc (E & E) was tasked by Alaska Department of Environmental Quality (ADEC) to compile information from state environmental agencies regarding inhalation of diesel vapors in indoor air and to recommend a method for dealing with vapors from diesel releases. Migration of vapors into indoor air may result from a leaking underground storage tank (LUST), overfilling of an underground storage tank (UST), or other incident associated with a UST containing diesel fuel oil.

Currently, direction on cleanup of petroleum compounds is provided in *Guidance for Cleanup of Petroleum Contaminated Sites* (ADEC 2000). In this guidance, four methods are described for determining cleanup levels for soil and groundwater. Included in Method 2 are soil and groundwater cleanup levels. For soil, cleanup levels are provided for the inhalation of vapor exposure pathway. The cleanup level for DRO in soil that is protective of inhalation of vapors in outdoor air is 12,500 mg/kg. However, ADEC is concerned that diesel fuel contamination in soil may pose unacceptable risks to residents for exposure to vapors in indoor air.

The U.S. Environmental Protection Agency (EPA) has released a guidance document entitled, *Supplemental Guidance For Evaluating the Vapor Intrusion to Indoor Air Pathway* (2001) that deals with indoor air impacts of subsurface soil contamination. The document outlines three tiers or levels of evaluation for the vapor intrusion to indoor air pathway. The initial step involves a general site characterization where the determination is made whether or not a complete exposure pathway may potentially exist. If an incomplete exposure pathway cannot be confirmed, then the site evaluation proceeds to the second tier where contaminant concentrations are compared to generic risk-based criteria. If these criteria are exceeded, then the evaluation proceeds to the third tier, involving a site-specific pathway evaluation. This final step involves screening site data against site- and media-specific criteria. If tier three site-specific criteria are exceeded, then corrective actions are necessary to reduce exposure.

The following technical memorandum summarizes cleanup policies for diesel fuel oil vapors based on migration of vapors into indoor air for the states of Washington, Oregon, Minnesota, Wisconsin, Michigan, Maine, and Massachusetts. Representatives from the California Environmental Protection Agency's Environmental Health Hazard Assessment group and Environment Canada could not be contacted for this report. Following the state summaries is a general summary and recommendation for ADEC in evaluating migration of diesel fuel oil vapors in subsurface soil and groundwater into indoor air.

2. State Summaries

Representatives from state environmental protection agencies were contacted regarding policies for cleanup of LUSTs containing diesel fuel oil. In addition, E & E reviewed guidance and policy documents that were available on the World Wide Web for each state.

2.1 Washington

The Washington State Department of Ecology (Ecology) regulates the cleanup of hazardous substances including diesel fuel oil. Methods for evaluating diesel contamination in soil, groundwater, surface water, and air are provided in the Model Toxics Control Act (MTCA) and Ecology's *Workbook for Calculating Soil and Ground Water Cleanup Levels for Petroleum Contaminated Sites* and *User's Guide* (Ecology 2001). The workbook and user's guide do not provide methods for estimating indoor air concentrations based on contaminant concentrations in soil. However, MTCA mandates that exposure to diesel fuel oil vapors in indoor air must be evaluated when the diesel concentration in soil is greater than 10,000 mg/kg. MTCA further states that soil concentrations protective of indoor and ambient air will be determined on a site-specific basis according to one of the three following methods: 1) concentrations of fractionated diesel range organics (DRO) in soil vapor are measured directly and then the fraction concentrations are compared to air cleanup levels; 2) indoor air concentrations of DRO fractions are measured directly and then compared to air cleanup levels; or, 3) modeling methods for estimating indoor air DRO concentrations may be used upon approval by Ecology. If any cleanup levels are exceeded, then the next step is corrective action to eliminate the exposure.

Hun Seak Park, toxicologist at Ecology, did not have confidence in the use of models to estimate DRO concentrations in indoor air. Instead, he recommended the use of the Method A soil cleanup level for diesel of 2,000 mg/kg. Mr. Park indicated that this soil concentration level would be protective of exposure via inhalation of vapors in indoor air, particularly since DRO generally have low volatility. In addition, Mr. Park indicated that benzene would be an acceptable indicator compound for monitoring DRO vapors and estimating risk.

2.2 Oregon

The Oregon Department of Environmental Quality (ODEQ) provides guidance on evaluating exposure to diesel fuel contamination in various media in *Risk-Based Decision Making for Cleanup of Petroleum-Contaminated Sites* (ODEQ 1999). ODEQ does not routinely require indoor air or soil vapor sampling to evaluate risks from inhalation of vapors migrating from subsurface soil contamination. This pathway is normally evaluated by comparing soil concentrations of petroleum product indicator compounds to risk-based concentrations (RBCs). Indicator compounds include benzene, toluene, ethylbenzene, and total xylenes (BTEX), and polynuclear aromatic hydrocarbons (PAHs). ODEQ's guidance recommends comparing concentrations of indicator compounds in soil and/or groundwater to generic exposure pathway-specific RBCs, which includes RBCs for vapor intrusion into buildings from soil and groundwater. However, most of the RBCs for PAHs are not risk-based concentrations; rather, the RBCs are based on soil saturation limits because it is assumed that these compounds do not pose

a health risk via vapor intrusion into buildings. Exceedance of these values would indicate the presence of free-product. Actual health-based RBCs were calculated for six diesel fuel oil indicator compounds using the Johnson and Ettinger (J & E; 1991) model: benzene, toluene, naphthalene, propylbenzenes, and 1,3,5-trimethylbenzene. Alternatively, site-specific RBCs may be calculated using a site-specific volatilization factor for each indicator compound. If any indicator compounds are present at concentrations exceeding RBCs, corrective action must be taken.

2.3 Michigan

The state of Michigan's Department of Environmental Quality (MDEQ) provides "look-up tables" that contain cleanup levels for contaminants in soil and groundwater, based on different exposure pathways. Included in the table are volatilization to indoor air inhalation levels for soil and groundwater. MDEQ's Operational Memorandum 4, Attachment 8 (MDEQ 1998) describes the development of cleanup levels for the indoor air inhalation pathway and discusses possible remedies for sites with contaminant levels exceeding cleanup levels. James Milne of MDEQ's LUST Division indicated that most constituents of diesel fuel oil (PAHs) are not volatile, and therefore, do not pose an unacceptable risk of exposure via inhalation. For those constituents of diesel fuel oil with a Henry's Law Constant greater than 1E-05 atm*m^3/mol, a modified version of the J & E (1991) model was used to develop cleanup levels for the volatilization to indoor air exposure pathway (MDEQ 1998). These levels are compared to site constituent concentrations in order to assess the inhalation of indoor air exposure pathway. Corrective action is necessary when cleanup criteria are exceeded. Mr. Milne reported that cleanup levels for whole product, or DRO, are used only when PAHs are not detected but aesthetics are a concern (stains and odors).

2.4 Minnesota

The Minnesota Pollution Control Agency (MPCA) mandates that a Vapor Receptor Survey be conducted at all LUST sites, as described in *Potential Receptor Surveys and Risk Evaluation Procedures at Petroleum Release Sites* (MPCA 2001). If it has been shown that a complete exposure pathway exists between the subsurface soil and/or groundwater contamination and human receptors, MPCA requires that air samples be collected over a 24-hour period using SUMMA canisters, and the contents analyzed for volatile organic compounds (VOCs) per EPA method 18 (MPCA 2001). Air samples are to be collected under a "worst case" scenario, meaning all windows are to be closed and the furnace should be running. Any confirmed detection of VOCs is considered unacceptable; therefore, the presence of VOCs leads to a corrective action to eliminate the exposure. Steven Thompson of the MPCA indicated that analytical data for petroleum compounds in soil cannot be used to assess risk of inhalation of petroleum vapors in indoor air; MPCA does not support the use of models to extrapolate contaminant concentrations in indoor air from contaminant concentrations in soil.

2.5 Wisconsin

The Wisconsin Department of Natural Resources – Environmental Protection (DNREP) regulates LUSTs through the Remediation and Redevelopment Program. Resty Pelayo of DNREP reported that concentrations of DRO up to 100 mg/kg in soil are considered acceptable. Soil concentrations are used to estimate potential soil vapor concentrations and ultimately, are used to protect against the indoor air inhalation exposure pathway. DNREP uses the U.S. Environmental Protection Agency's (EPA) soil screening calculations as default cleanup values. DNREP provides modifications to EPA's calculations to ensure representativeness for the state of Wisconsin (DNREP 2002). Using EPA's soil screening calculations, acceptable soil concentrations are derived which are assumed to be protective of exposure via inhalation of indoor air. Using this method, constituents of diesel fuel oil, such as BTEX and PAHs, are used

as indicators for diesel fuel oil toxicity. Wisconsin did not have guidance specific to LUSTs or other petroleum releases.

2.6 Maine

The state of Maine Department of Environmental Protection (MEDEP) has published guidance on evaluating exposure to petroleum vapors in indoor air entitled, *Field Guideline For Protecting Residents From Inhalation Exposure To Petroleum Vapors* (2000). This guidance provides instruction on conducting a visual inspection of the release area and determining if the vapor intrusion to indoor air pathway is complete. If this is a complete pathway, the guidance instructs the user on the collection of air samples necessary to evaluate exposure to petroleum vapors in indoor air. Air samples are to be collected under "worst case" conditions over a 24-hour time period, using SUMMA canisters and analyzed for the following indicator compounds: BTEX, n-hexane, n-nonane, naphthalene, and methyl-tert-butyl ether. Concentrations of indicator compounds are screened against health-based action levels provided in the guidance (MEDEP 2000). Any exceedance of the action levels results in a remedial action.

George Seel of MEDEP stated that there is not a good correlation between petroleum concentrations in soil and modeled concentrations in soil vapor or air; therefore, MEDEP does not recommend the use of models, such as the J & E (1991) model. Mr. Seel indicated that no free product or saturated soil is allowed in Maine and that the generic soil cleanup level for DRO is 200 to 400 ppm, using a field headspace analysis.

2.7 Massachusetts

The Massachusetts Department of Environmental Protection (MADEP) recommends evaluating exposure to diesel fuel oil vapors in indoor air in the event of a fuel oil tank release. In *Implementation of the MADEP VPH/EPH Approach* (MADEP 2001), MADEP recommends evaluating soil gas using a flame ionization detector (FID) or more sophisticated analytical technique and then comparing results to generic screening values for hydrocarbon fraction groups, BTEX, and acenaphthalene, 2-methylnaphthalene, naphthalene, and phenanthrene. The soil gas data may also be used in a screening-level or site-specific risk assessment to evaluate exposure to soil gas vapors. The MADEP provides a web-based calculation spreadsheet for estimating risks using soil vapor data, the *#2/Diesel Risk Assessment Short Form-Residential Scenario* (MADEP 1997). The *#2/Diesel Short Form* streamlines the site-specific risk assessment process and determines if vapors in indoor air present unacceptable risks. Exceedance of acceptable risk levels leads to implementation of a corrective action.

Paul Locke of MADEP indicated that the department will accept estimated concentrations of hydrocarbon fractions, BTEX, and PAHs in soil vapor or indoor air using variations of the J & E (1991) model although analytical data is preferred. Modeled air concentrations may also be used in the *#2/Diesel Short Form.* However, from Mr. Locke's experience, use of soil analytical data in the J & E (1991) model usually results in an underestimation of actual vapor concentrations and the model will overestimate vapor concentrations when groundwater data is used or when the release is old and the petroleum products have biodegraded.

Mr. Locke stated that indoor air samples are the least desirable for evaluating exposure due to uncertainty in representativeness of air sampling. Mr. Locke also indicated that it is not acceptable to assess risk of exposure to diesel fuel oil vapors in indoor air using only benzene as an indicator compound.

3.0 Summary

Soil cleanup levels for DRO and/or indicator compounds are used by the states of Washington, Oregon, Michigan, and Wisconsin to protect residents from exposure to diesel fuel oil vapors in indoor air. Washington is the only state with criteria based on DRO while the other states use BTEX and PAHs as indicator compounds of diesel fuel oil toxicity. The states of Oregon, Michigan, and Wisconsin use the J & E (1991) model to estimate concentrations of indicator compounds in air or vapor based on their respective concentrations in soil.

The states of Minnesota and Maine require the use of air sampling data to evaluate exposure to diesel fuel oil vapors in indoor air based on a lack of confidence in modeling techniques. Minnesota uses only VOCs for indicator compounds while Maine requires the analysis of BTEX and naphthalene, n-hexane, and n-nonane. The state of Massachusetts requires the collection of soil vapor samples and analysis of hydrocarbon fractions, BTEX, and PAHs (naphthalene and phenanthrene) and modeled vapor or air concentrations are considered preferable to actual air monitoring data.

With the exception of Washington State, all agency representatives stated that it is unacceptable to use only benzene as an indicator of diesel fuel oil whole product toxicity. For these states, a suite of PAHs and BTEX were recommended and/or required. The state of Massachusetts appears to have the most comprehensive and technically advanced guidance and methods for evaluating residential exposure to petroleum vapors in indoor air.

The Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) calculated risk-based screening levels for a number of example sites using their Direct Method Petroleum Hydrocarbon fractionation method and the general ASTM risk-based corrective action approach, which evaluates indoor air using the J & E (1991) model. The range of risk-based screening levels (based on a hazard index of 1) that the TPHCWG calculated for diesel fuel ranged from about 100 to 2,000 mg/kg, with the 25^{th} to 75^{th} percentile ranging from about 200 to 600 mg/kg and a 50^{th} percentile of about 350 mg/kg (TPHCWG 1999).

4.0 Recommendations

E & E recommends that ADEC conduct a three-phase evaluation of subsurface diesel fuel oil releases. These phases or levels would include (1), visual inspection and development of a conceptual site model (CSM); (2), collection of samples and screening against generic cleanup criteria; and (3), screening against site-specific cleanup criteria.

The first phase involves a visual inspection of the release site and development of a CSM to determine if there is a complete exposure pathway (e.g., if there is a potential for diesel fuel oil vapors in subsurface soil or groundwater to infiltrate indoor air). If the release is recent and a complete exposure pathway is known to exist, a PID or FID and oxygen meter should be used to determine if the indoor airspace is safe for entry and if evacuation of the building is necessary. If the determination of an incomplete exposure pathway cannot be made, then proceed to the second phase.

The second phase involves collection and analysis of contaminated media at the release site and screening against generic cleanup criteria. Each state varied in the media (soil, soil vapor, or air) used to evaluate fuel oil vapors in indoor air. As stated in the previous section, the MADEP appears to have the most comprehensive approach for evaluating petroleum hydrocarbon contamination. Therefore, use of MADEP's soil vapor sampling and analytical methods is recommended. However, if implementing MADEP's soil vapor screening methods is cost-prohibitive, E & E recommends practices similar to those outlined in Oregon's *Risk-Based Decision Making for Cleanup of Petroleum-Contaminated Sites* (ODEQ 1999) or EPA's soil

screening calculations. The State of Oregon and the EPA's methods involve the use of the J & E (1991) model to develop soil cleanup levels for BTEX and naphthalene based on the vapor intrusion to indoor air pathway. Most states require corrective action if generic cleanup levels are exceeded at this point; although, generic cleanup levels may be overly conservative. Therefore, E & E recommends conducting a third phase in the evaluation if the generic cleanup levels are exceeded.

The third and final phase involves the development of site-specific cleanup levels (e.g., site-specific soil parameters, such as fraction of organic carbon, etc). If site-specific cleanup levels are exceeded, a corrective action must be implemented.

This three-phase approach is similar to the approach outlined in the EPA's document, *Supplemental Guidance For Evaluating the Vapor Intrusion to Indoor Air Pathway* (2001), described in Section 1.0 of this memorandum.

5.0 References

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