![northgate environmental management, inc.]

MEMORANDUM

From: Deni Chambers
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Date: ~~June 29~~November 12, 2010

To: Shannon Harbour, PE
Nevada Division of Environmental Protection

CC: Brian Rakvica, McGinley and Associates
Jim Najima, Nevada Division of Environmental Protection
Teri Copeland
Paul Black, Neptune and Co.

RE: Revised Technical Memorandum: Screening-Level Indoor Air Health Risk Assessment for the 2008 Tronox Parcels A/B Soil Gas Investigation, BMI Industrial Complex, Clark County, Nevada

1.0 INTRODUCTION

The objective of this Technical Memorandum is to present the results of a screening-level indoor air health risk assessment (HRA) for the Phase B Source Area Soil Gas Investigation that Basic Environmental Company (BEC) and Tronox performed for the Tronox Parcels "A" and "B" (portions of APN Nos. 178-01-401-001, 178-12-101-002, and 178-12-201-006 [Note: Parcel 178-12-601-005, formerly part of Tronox Parcel B, has been sold and is excluded from this analysis]). Parcels A/B will collectively be referred to as "the property" for the purposes of this Technical Memorandum. The property is located north of Warm Springs Road, 1/4 mile west of the intersection with Boulder Highway, in Henderson, Nevada. Figure 1 shows details of Parcels A/B and the soil gas sampling locations. The Technical Memorandum ~~only~~ presents a summary of the data included in this assessment, including results of the *Data Validation Summary Report Phase B Source Area Investigation Soil Gas Survey* (ENSR 2008a; approved by the Nevada Division of Environmental Protection [NDEP] on October 20, 2008) and data usability evaluation, as well as the methods and results of the screening-level indoor air HRA ~~and does not present investigation, data summary, data usability, or data adequacy information~~. This Technical Memorandum also provides a brief summary of the ~~information is provided in the Nevada Division of Environmental Protection (NDEP) approved~~ *Technical Memorandum – Data Review for 2007 Tronox Parcels A/B Investigation* dated February 11, 2008 (BEC 2008; approved by NDEP on April 8, 2008)~~, and the *Data Validation Summary Report* for the soil gas survey (Tronox 2008; approved by NDEP on October 20, 2008)~~.

This revision of the Screening-Level Indoor Air Health Risk Assessment Memorandum, Revision ~~2~~3, incorporates comments received from the NDEP, dated ~~May 13~~August 31, 2010, on Revision ~~1~~ 2 of the report, dated ~~March 25~~June 29, 2010, along with clarifying comments received from NDEP during a September 7, 2010 teleconference (September 7, 2010 meeting minutes). ~~.~~ The NDEP comments and BRC's response to the August 31, 2010 ~~se~~ comments are provided separately; however, a redline/strikeout version of the text showing the revisions from the ~~March 25~~June 29, 2010 version of the Technical Memorandum in response to NDEP's comments is provided in Attachment A.[1]

2.0 CONCEPTUAL SITE MODEL

The conceptual site model (CSM) is used to describe relationships between chemicals and potentially exposed human receptor populations, thereby delineating the relationships between the suspected sources of chemicals identified at the property, the mechanisms by which the chemicals might be released and transported in the environment, and the means by which the receptors could come in contact with the chemicals. The CSM provides a basis for defining data quality objectives and developing exposure scenarios.

The CSM considers current and potential future land-use conditions. Currently, the property is undeveloped; however, the planned future use of the property is for commercial purposes. Given the planned development of the property, potential human receptors include on-site construction workers, on-site indoor commercial workers, on-site outdoor maintenance workers, and on-site visitors, which is consistent with the Tronox *HRA Work Plan* (Northgate 2010) ~~and the *BRC Closure Plan* (BRC, ERM, and DBS&A, 2009)~~. Although several potential human receptors may occur on the property in the future, this screening-level HRA focuses on indoor commercial workers. This receptor is considered to have the highest level of exposure to volatile organic chemicals (VOCs) in indoor air at the property. Other receptors, such as site visitors, will have lower exposures, and thus lower risk estimates. Therefore, risk estimates generated for future on-site indoor commercial workers will be protective of other potential receptors at the property.

A separate screening-level HRA evaluated risks from exposure to soil at Parcels A/B. The results from that screening-level HRA are provided in the *Technical Memorandum – Data Review for 2007 Tronox Parcels A/B Investigation* dated February 11, 2008 (BEC 2008; approved by NDEP on April 8, 2008). However, these exposures did not account for potential migration of VOCs from the subsurface into indoor air. In general, the United States Environmental Protection Agency (USEPA) does not recommend evaluating the indoor air exposure pathway using soil matrix data (USEPA 2002a). Because groundwater beneath a

[1] Revisions made to correct typographical or minor grammatical errors are not shown in the redline/strikeout version to facilitate readability of the document.

portion of the property is considered a potential VOC source area, soil gas data were collected. The soil gas data are the focus of this screening-level indoor air HRA. It should be noted that the pending site-wide soil gas risk assessment will more fully discuss the site-wide conceptual model, including potential groundwater and soil sources and the impact of these sources on the measured soil gas concentrations, including data collected in Parcels A/B.

3.0 SCREENING-LEVEL INDOOR AIR HEALTH RISK ASSESSMENT

As discussed ~~above~~in Section 2.0, the previous screening-level HRA for Parcels A/B (BEC 2008) did not consider the indoor air pathway. Therefore, soil gas data were collected at several locations throughout Parcels A/B to specifically evaluate this potential exposure pathway at the property.

Human health risks are represented by estimated theoretical upper-bound cancer risks and non-cancer hazards derived in accordance with standard USEPA methods. These values will be compared to the following criteria:

1. For non-carcinogenic compounds, the NDEP non-cancer risk management target is a cumulative hazard index (HI) of one or less (NDEP 2009). If the screening HI is determined to be greater than 1.0, target organ-specific HIs will be calculated for primary and secondary organs. The final risk goal will be to achieve target organ-specific non-carcinogenic HIs of less than 1.0; and
2. For most known or suspected chemical carcinogens, the NDEP point of departure is a cumulative incremental lifetime cancer risk (ILCR) of 1×10^{-6}.[2]

This screening-level indoor air HRA follows the basic procedures outlined in USEPA's *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (RAGS Part A; USEPA 1989). Other guidance documents, including USEPA's *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)* (U.S. EPA, 2009), were also consulted for the screening-level indoor air HRA.

3.1 Data Review and Evaluation

Soil gas samples were collected in Parcels A/B as part of the Phase B Source Area Soil Gas Investigation. The details of the soil gas sampling are provided in the *Phase B Source Area Investigation Soil Gas Survey Work Plan* (Soil Gas Work Plan; ENSR 2008b). Briefly, sample

[2] There are exceptions to this general rule, including dioxins/furans and asbestos, each of which is evaluated separately from other carcinogenic chemicals (Northgate 2010).

locations were based on the *Phase A Source Area Investigation Results* (ENSR 2007), which identified the presence of several VOCs in soil and/or groundwater at the Tronox site. According to the Soil Gas Work Plan, soil gas samples were collected to evaluate VOCs from a groundwater source (Parcels A/B) or to investigate Nevada Auto Parts as a potential VOC source (Parcel B). All of the soil gas samples in Parcels A/B were collected at 5 feet below ground surface (bgs), and analyzed for VOCs according to EPA Method TO15.

The soil gas data, including those from Parcels A/B, have been validated as documented in the *Revised Data Validation Summary Report [DVSR], Phase B Source Area Investigation Soil Gas Survey, Tronox LLC Facility, Henderson, Nevada*, (ENSR 2008a; approved by NDEP on October 20, 2008). An electronic copy of the DVSR for the soil gas data, including laboratory reports, is provided in Attachment D. A data usability evaluation for the soil gas samples collected in Parcels A/B is provided in Attachment E. This evaluation was conducted in accordance with USEPA and NDEP guidance. As discussed further in the attachment, a small number of data points were found to be qualified based on method blank and quantitation issues, but were deemed acceptable. Based on this evaluation, all Data Usability requirements were met and all Parcel A/B soil gas data were deemed to be usable for risk assessment purposes.

3.2 Selection of Chemicals of Potential Concern

As shown in Figure 1, nine soil gas samples were collected in Parcels A/B. The validated data for these samples, including the number of detections, detection frequency, minimum and maximum detections, minimum and maximum detection limits, mean, median, and standard deviation, are summarized in Table 1; the raw data are provided in Attachment B. Consistent with NDEP (2008) guidance, one-half the limit of detection was used in calculating the mean, median, and standard deviation; the sample quantitation limit (SQL) was used as the detection limit. For purposes of this screening-level indoor air HRA, all chemicals detected in at least one of the nine soil gas samples collected at Parcels A/B were identified as chemicals of potential concern (COPCs) at the property.

For those chemicals that were not detected in any of the soil gas samples, their detection limits were compared to shallow soil gas to indoor air vapor intrusion screening levels from USEPA [2002a; Table 2c (Generic Screening Levels and Summary Sheet; Risk = 1×10^{-6}], which are based on a residential scenario assuming a soil gas to indoor air attenuation factor (alpha) of 0.1. These levels are considered sufficiently conservative for purposes of evaluating detection limits (as opposed to 1/10th the screening level) for the following reasons. First, future use of Parcels A/B will be commercial rather than residential. Second, USEPA provides screening levels for both shallow and deep soil gas. “Shallow” soil gas is defined as soil gas samples collected just below the foundation to depths less than 5 feet below the foundation, whereas "deep" soil gas is defined as soil gas samples collected from just above the groundwater table or from depths greater than 5 feet below the foundation. For deep soil gas, the generic screening levels are based on an alpha of 0.01, resulting in screening levels that are a factor of 10 higher than those for shallow soil gas. Because soil gas samples in Parcels A/B were collected at 5 feet bgs, comparison to either the shallow soil gas or deep soil gas screening levels may be justifiable, and the shallow soil screening levels were used to be conservative. As shown in Table 1, none of the chemicals that were not detected in any of the soil gas samples had detection limits that exceeded their respective screening levels. Therefore, their exclusion should not affect the results of the evaluation. It should be noted that screening levels have not been developed for three chemicals that were not detected in any soil gas sample (2-methoxy-2-methyl butane, ethyl t-butyl, ether, and isopropyl ether). The maximum detections limits for these chemicals were very low (0.085, 0.087, and 0.1 µg/m^3, respectively); therefore, exclusion of these chemicals also should not affect the results of the screening-level indoor air HRA.

3.~~2~~3 Determination of Exposure Point Concentrations

A representative exposure point concentration is a COPC-specific and media-specific concentration value. In risk assessment, these exposure concentrations are values incorporated into the exposure assessment equations from which potential baseline human exposures are calculated. In general, U.S. EPA (1992) recommends using the 95th upper confidence limit (UCL) of the arithmetic mean concentration for purposes of estimating reasonable maximum or upper-end exposures. However, as discussed further in Section 3.5, not all soil gas data appear to be from a single population. Therefore, ~~For~~ for purposes of this screening-level indoor air HRA, the maximum detected concentration was used, which is consistent with NDEP's comments to previous versions of this Technical Memorandum.

3.~~2~~3.1 Indoor Air

The migration of COPCs from the subsurface and dispersion into indoor air were estimated using the USEPA spreadsheet-based Johnson and Ettinger (J&E) model (USEPA 2004a). The model is based on the vapor intrusion model published by Johnson and Ettinger (1991). The J&E model is a screening-level model, which incorporates both convective and diffusive mechanisms for estimating the transport of chemical vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above the source of contamination. The model is constructed to calculate steady-state vapor transport (infinite source). The maximum detected concentrations of the COPCs in soil gas, which were used as the exposure point concentrations for the indoor air exposure pathway, are presented in Table 1.

Either site-specific or default physical properties and building characteristics contained in the USEPA J&E spreadsheet model were used in this evaluation. These values are presented in Table 2. Tables 3 and 4 present the indoor air concentrations predicted by the J&E model for each of the COPCs, depending on assumptions for building air exchange rate and vapor flow rate into the building, as discussed further below.

Where site-specific data were unavailable, the model default parameters for a sand soil were used. Parameters for a sand soil result in the most conservative indoor air estimates. ~~Therefore, the modeling performed for the property should be considered a conservative estimate of potential indoor air risks.~~ The model input parameter that considers soil moisture is the water-filled porosity, which is determined by the gravimetric moisture content and the dry bulk density. Although there are adequate gravimetric moisture content data from the site itself (as determined using ASTM D2216), there is limited dry bulk density data for the general area; however, this information is available from the Borrow Area investigation (BRC and ERM 2007). Using an average dry bulk density from the Borrow Area data of 1.83 g/cm^3 and an average gravimetric moisture content from site data of 4.92 percent results in a water-filled porosity value of 0.09. In addition, the average effective porosity (which generally equates to total porosity) for the Borrow Area investigation was 0.30. Therefore, these values (bulk density = 1.83 g/cm^3; total porosity = 0.30; water-filled porosity = 0.090) are used in the modeling effort for the property.

With regard to building parameters, USEPA provides a recommended value for the air exchange rate for a residential building, but not a commercial building, in their J&E Model User's Guide (USEPA 2004a). The California Environmental Protection Agency (Cal-EPA) recommends a value of 1 per hour (1/hr) for commercial buildings based on the California Energy Commission's *Manual for Compliance with the 2001 Energy Efficiency Standards (for Nonresidential Buildings, High-Rise Residential Buildings and Hotels/Motels;* Cal-EPA 2005). The Michigan Department of Environmental Quality (MDEQ) recommends a value of 2/hr. The basis for this latter value is two-fold: First, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) *Draft BSR/ASHRAE Standard 62-1989R, Ventilation for Acceptable Indoor Air Quality* suggests that system rates for total supply air in a general office will be approximately 1/hr. Second, natural ventilation, infiltration, and entrance and egress into and out of the building will increase air exchange rates above the approximate 1/hr provided by mechanical systems (Michigan Environmental Science Board 2001). To address the uncertainty in this input parameter, a range of estimated indoor air concentrations and corresponding risk estimates based on an air exchange rate of 1/hr or 2/hr were estimated (see Tables 3 and 4, respectively).

Furthermore, USEPA does not provide recommended values for floor length and width of the enclosed space. The MDEQ does provide a recommended default value for the size of a hypothetical commercial building of 4,000 square feet (ft^2) or 372 square meters (m^2; Michigan Environmental Science Board, 2001). This value is based on data provided in a 1994 U.S. Department of Energy (DOE) report entitled *Commercial Building Characteristics 1992*, which documents the results of a Commercial Buildings Energy Consumption Survey. The most recent survey was completed in 2003 and the results were presented in a 2006 report issued by the U.S. Energy Information Administration (USEIA 2006). The data presented in this report are similar to that presented in the 1994 DOE report in that the majority of commercial buildings (other than malls) are between 1,000 $feet^2$ and 5,000 $feet^2$ in size and a single story, regardless of region of the country. In addition, the reported median square footage (the metric used by MDEQ) for different categories of commercial buildings nationwide ranges from 3,000 ft^2 to 7,000 ft^2. For purposes of this screening-level indoor air HRA, a value of 2000 centimeters (cm) was assumed for both the floor length and width, which is approximately equal to the default value of 4000 ft^2 (372 m^2) recommended by MDEQ.

Finally, the vapor flow rate into a building (Q_{soil}) is a controversial input parameter in the J&E model. As originally conceived, this value was calculated using a "perimeter crack model" by Nazaroff based on various site-specific or default values related to soil vapor permeability, pressure differentials, and size of cracks; however, a wide range of values can be predicted because of the model's sensitivity to estimates of soil vapor permeability (USEPA 2004a). Consequently, EPA provides a recommended "default" value for vapor flow rate into residential buildings, but not commercial buildings, in their J&E Model User's Guide (USEPA 2004a). The recommended default value is 5 L/m, which is based on empirical data collected in residences; however, such data for commercial buildings are lacking. Cal-EPA has adopted USEPA's recommended default value for Q_{soil} for residential buildings. For commercial buildings, Cal-EPA recommends scaling the default residential value based on the size of the commercial building (e.g., if the commercial building is twice the size as the default residential building, then the Q_{soil} value is doubled; Cal-EPA 2005). To address the uncertainty in this parameter, a range of estimated indoor air concentrations and corresponding risk estimates were estimated based on a scaled Q_{soil} value (4 × 5 L/m or 20 L/m because the default commercial building size described above is 4-times the default residential building size) as recommended by Cal-EPA and a calculated Q_{soil} based on a sand soil (see Tables 3 and 4, respectively).

3.~~3~~ 4 Risk Assessment Methodology

The method used in the screening-level indoor air HRA consists of several steps. The first step is the determination of exposure point concentrations representative of the particular

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area (see above). The second step is fate and transport modeling to predict concentrations that may be present when direct measurements are not available. The third step is the exposure assessment for the various receptors present in the particular areas. The fourth step is to define the toxicity values for each COPC. The final step is risk characterization where theoretical upper-bound ILCRs and non-cancer HIs are calculated. The ~~*BRC Closure Plan* (BRC, ERM, and DBS&A 2009) and~~ *Tronox HRA Work Plan* (Northgate 2010) provides a full discussion on the risk assessment methodology for the project, and is used as the basis for ~~in~~ this screening-level indoor air HRA. Specifically, the procedures outlined in the following sections of the *Tronox HRA Work Plan* were followed in this assessment:

- Section 3.3.3 regarding the evaluation of indoor air
- Section 4.2.1 regarding the estimation of inhalation exposure (Equation 9, assuming the entire 8-hour workday is spent indoors)
- Section 5.0 regarding hierarchy for selecting toxicity criteria
- Section 6.0 regarding the estimation of excess cancer risks (Equations 16 and 17) and noncancer hazard indexes (Equations 22 and 23) and assessment of uncertainty.

Table 2 presents each of the exposure parameters used in the screening-level indoor air HRA. Toxicity values, when available, are published by the USEPA in the online Integrated Risk Information System (IRIS; USEPA 2010) and the Health Effects Assessment Summary Tables (HEAST; USEPA 1997). Unit risk factors (URFs) are chemical-specific, experimentally-derived potency values used to calculate the risk of cancer resulting from exposure to carcinogenic chemicals. A higher value implies a more potent carcinogen. Reference concentrations (RfCs) are experimentally derived “no-effect” values used to quantify the extent of adverse non-cancer health effects from exposure to chemicals. Here, a lower RfC implies a more potent toxicant. These criteria are generally developed by USEPA risk assessment work groups and listed in USEPA risk assessment guidance documents and databases. The ~~hierarchy for selecting toxicity criteria presented in the *BRC Closure Plan* (BRC, ERM, and DBSA 2009) and *Tronox HRA Work Plan* (Northgate 2010) was used, and the~~ identified values, including the source, are presented in Tables 3 and 4.

3.~~4~~5 Uncertainty Analysis

Risk estimates are values that have uncertainties associated with them. These uncertainties, which arise at every step of a risk assessment, are evaluated to provide an indication of the uncertainty associated with a risk estimate. Risk assessments are not intended to estimate the true risk to a receptor associated with exposure to chemicals in the environment. In fact, estimating the true risk is impossible because of the variability in the exposed or potentially exposed populations. Therefore, risk assessment is a means of estimating the probability that an adverse health effect (*e.g.*, cancer, impaired reproduction) will occur in a receptor to assist in decision making regarding the protection of human health. The multitude of conservative assumptions used in risk assessments guard against underestimation of risks.

Risk estimates are calculated by combining site data, assumptions about individual receptor's exposures to impacted media, and toxicity data. The uncertainties in this screening-level indoor air HRA can be grouped into four main categories that correspond to these steps:

- Uncertainties in environmental sampling and analysis
- Uncertainties in fate and transport modeling
- Uncertainties in assumptions concerning exposure scenarios
- Uncertainties in toxicity data and dose-response extrapolations

Additional discussion on the uncertainties associated with the screening-level indoor air HRA is provided below.

The screening-level indoor air HRA for the property was based on the sampling results obtained from a soil gas investigation conducted in 2008. Errors in sampling results can arise from the field sampling, laboratory analyses, and data analyses. Errors in laboratory analysis procedures are possible, although the impacts of these sorts of errors on the risk estimates are likely to be low. The environmental sampling at the property is one source of uncertainty in the evaluation. As shown in Figure 1, the sampling locations are spread across the property, and sampling was performed using approved procedures.

~~In addition, the~~ The maximum detected concentration was used as the exposure point concentration, which is generally considered to be a conservative assumption because receptors are unlikely to be exposed to the maximum concentration of all COPCs over an extended period of time. As discussed further in Section 3.6, chloroform contributed almost exclusively to the non-cancer hazard index and cancer risk estimates. Of the nine soil gas samples collected in Parcels A/ B, the highest concentrations of chloroform were detected in three samples adjacent to one another in Parcel B and the concentrations detected in these samples were much higher than the chloroform concentrations detected in the other six samples. Further, the three highest detected concentrations were relatively similar (440, 400, and 270 micrograms per cubic meter [µg/m^3]), suggesting that the maximum chloroform concentration may be reasonably representative of chloroform concentrations in soil gas in this area of Parcel B.

Figure 2 presents the chloroform results for soil gas and groundwater. As shown, soil gas locations were placed at the farthest down-gradient property boundary, while other locations were spread randomly throughout the Parcels. Some soil gas locations were co-located near groundwater monitoring wells. Higher soil-gas concentrations were detected in Parcel B where higher concentrations of chloroform in groundwater were also detected. Additionally, chloroform was detected in groundwater at a monitoring well located directly up--gradient from Parcel B (MW23) at higher concentrations than those reported in Parcels A/B. Up-gradient groundwater concentrations likely contribute to the measured soil gas concentrations in Parcel B. Finally, based on the soil gas sampling locations, and considering these locations in context of the entire site-wide investigation, the sample results are deemed representative to evaluate Parcel A/B soil gas conditions.

The J&E model relies on a series of assumptions regarding site soils and building characteristics. In this assessment, soil physical parameter data for this site or nearby sites were used as available; otherwise, characteristics associated with "sand" were conservatively assumed. Because the site has not yet been developed, assumptions had to be made regarding the type and size of future buildings. For purposes of this screening-level assessment, a range of indoor air concentrations and corresponding risks were estimated based on a range of values for building air exchange rate and vapor flow rate into the building to address some of the uncertainty in these model input parameters.

The indoor commercial worker is the only scenario quantitatively evaluated in this screening-level indoor air HRA. NDEP default assumptions were used for exposure frequency (250 days per year) and duration (25 years; NDEP 2009), which are consistent with USEPA assumptions for a reasonable maximum exposure (RME) scenario (USEPA 2002b). Other receptors, such as site visitors, would not be expected to be at the site as frequently or for as long a period of time; therefore, conclusions regarding indoor commercial workers will be protective of other potential receptors at the property.

One of the largest sources of uncertainty in any risk assessment is the limited understanding of toxicity to humans who are exposed to the low concentrations that are generally encountered in the environment. The majority of the available toxicity data are from animal studies; these data are extrapolated using mathematical models or multiple uncertainty factors to predict what might occur in humans. Sources of conservatism in the toxicity criteria used in this screening-level indoor air HRA include:

- The use of conservative methods and assumptions to extrapolate from high-dose animal studies to predict the possible response in humans at exposure levels far below those administered to animals;
- The assumption that chemicals considered to be carcinogens do not have thresholds (i.e., for all doses greater than zero, some risk is assumed to be present); and

- The fact that epidemiological studies (i.e., human exposure studies) are limited and are not generally considered in a quantitative manner in deriving toxicity values.

In aggregate, these assumptions lead to overestimates of risk, such that the actual risk is unlikely to be higher than the estimated risk, but could be considerably lower~~ and, in fact, could be zero~~. It should be noted, however, that toxicity criteria have not been established for many of the chemicals detected at the property. These chemicals were not quantitatively evaluated in the screening-level indoor air HRA. Thus, the risks presented in this assessment could be underestimated as a result.

In summary, uncertainties from different sources are compounded in this screening-level indoor air HRA. For example, if a person's daily intake rate for a chemical is compared to an RfC to determine potential health risks, the uncertainties in the concentration measurements, exposure assumptions, and toxicities will all be expressed in the result. Because the exposure assumptions and toxicity criteria are considered conservative, the risk estimates calculated in this screening-level indoor air HRA are likely to overestimate rather than underestimate potential risks.

3.~~5~~ 6 Screening-Level Indoor Air Health Risk Assessment Results

This screening-level indoor air HRA has evaluated potential risks to human health associated with chemicals detected in soil gas at the Tronox Parcels A/B property. The theoretical upper-bound ILCRs and non-cancer health effects for the COPCs are presented in Tables 3 (assuming more conservative values for air exchange rate and vapor flow into the building) and 4 (assuming less conservative values for these same parameters). All calculation spreadsheets for this screening-level indoor air HRA are included in Attachment C.

The total cumulative non-cancer HI for future on-site indoor commercial workers at the property ranges from 0.0008 to 0.002. The largest contributor to the cumulative HI is chloroform. The HI values are well below NDEP's target HI of 1.0.

The theoretical upper-bound ILCR for future on-site indoor commercial workers at the property ranges from 5×10^{-7} to 1×10^{-6}. The risks are primarily driven by chloroform, which contributes approximately 90 percent of the theoretical upper-bound ILCR. These values are equal to or below NDEP's point of departure of 1×10^{-6}. It should be noted that chloroform was not detected in any of the 64 soil samples collected at the property (BEC, 2008). The apparent source of chloroform and other chemicals detected in soil gas is impacted groundwater located south and west (upgradient) of Parcels A/B.[3]

4.0 SUMMARY OF SCREENING-LEVEL SOIL HEALTH RISK ASSESSMENT

As stated previously, the results of the screening-level HRA for COPCs in soil at Parcels A/B are presented in the *Technical Memorandum – Data Review for 2007 Tronox Parcels A/B Investigation*, dated February 11, 2008 (BEC, 2008). These results are briefly summarized herein so that the results from both the soil and soil gas assessments can be considered in concert. The COPCs identified in soil were evaluated in three groups, i.e., chemicals (other than asbestos), radionuclides, and asbestos. For chemicals and radionuclides, ILCRs and HIs were estimated based on the maximum detected concentration and the USEPA Region 9 industrial preliminary remediation goals (PRGs) for chemicals (USEPA 2004b) and the USEPA industrial PRGs for radionuclides (U.S. EPA, 2007). For asbestos, the estimated risk for death from lung cancer or mesothelioma was estimated according to USEPA's (and subsequently NDEP's) asbestos risk assessment guidance (U.S. EPA, 2003). The results of the screening-level soil HRA can be summarized as follows:

- **Chemicals (other than asbestos):** The total cumulative non-cancer HI for future commercial/industrial receptors at the property is 0.~~27~~10.[4] The largest contributor to the cumulative HI is ~~lead~~total chromium. The total theoretical upper-bound ILCR for future commercial/industrial receptors at the property for non-radionuclides is 1×10^{-6}. The largest contributors to the cumulative ILCR are dioxins/furans, alpha-BHC and polycyclic aromatic hydrocarbons (PAHs).

- **Radionuclides:** The total theoretical upper-bound ILCR for future commercial/industrial receptors at the property for radionuclides is 3×10^{-6}. The largest contributor to the cumulative ILCR is uranium-238.

- **Asbestos:** The estimated risks for death from lung cancer or mesothelioma for asbestos exposures to outdoor maintenance worker receptors were below 1×10^{-6}. For construction workers, the best estimate and upper bound concentrations of asbestos

[3] A draft figure showing chloroform concentrations in soil gas and groundwater was provided as part of the Site-Wide Data meeting with NDEP on February 5, 2010. The presence of VOCs in soil gas and groundwater will be evaluated as part of the site-wide soil gas report for the Tronox facility.

[4] The total cumulative non-cancer HI reported in the cited document is 0.27; however, that value included lead. Because lead is evaluated separately from other noncarcinogens, the portion of the HI attributed to lead (0.17) was subtracted from the reported total HI of 0.27, resulting in an adjusted total HI of 0.10.

range from 1×10^{-7} (best estimate) to 8×10^{-7} (upper bound estimate) for chrysotile fibers, and from zero (best estimate) to 5×10^{-6} (upper bound estimate) for amphibole fibers (no long amphibole structures have been detected at the property).

5.0 SUMMARY

This Technical Memorandum presents the results of a screening-level indoor air HRA for COPCs in soil gas at Parcels A/B. All chemicals detected in soil gas were identified as COPCs, regardless of detected concentration or detection frequency. ~~Per NDEP's request~~Consistent with NDEP's comments to previous versions of this Technical Memorandum, t~~T~~he maximum detected concentration was used as the exposure point concentration. USEPA's J&E model was used to estimate indoor air concentrations for indoor commercial workers and associated non-cancer HIs and ILCRs. The estimated cumulative HI ranged from 0.0008 to 0.002, depending on the assumptions for air exchange rate and vapor flow into a building, and was driven primarily by chloroform. The cumulative ILCRs ranged from 5×10^{-7} to 1×10^{-6}, and were also driven by chloroform. The apparent source of chloroform and other chemicals detected in soil gas is impacted groundwater located south and west (upgradient) of Parcels A/B.

The results of a separate screening-level HRA for chemicals detected in soil at Parcels A/~~ and~~ B were also summarized so that the results from both screening-level HRAs can be considered in concert. All chemicals detected in soil above background concentrations were identified as COPCs. As with the soil gas assessment, the maximum detected concentration was used as the exposure point concentration to evaluate both commercial/industrial workers and construction workers. The estimated cumulative HI was 0.~~27~~ 10 and was driven by ~~lead~~total chromium. The estimated cumulative ILCR for non-radionculides was 1×10^{-6}, and was driven by dioxins/furans, alpha-BHC and PAHs. For radionuclides, the estimated cumulative ILCR was 3×10^{-6}, and was driven by uranium-238. Finally, the best estimates of risk associated with exposure to asbestos were below 1×10^{-6} whereas the upper-bound estimates ranged from 8×10^{-7} (chrysotile fibers) to 5×10^{-6} (amphibole fibers). It should be noted that chloroform was not detected in any of the 64 soil samples collected at the property.

Figure

1	Tronox Parcels A/B Phase B Soil Gas Sample Locations
2	Parcels A and B Chloroform Results in Soil Gas and Groundwater

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Tables

1	Parcels A/B Soil Gas Data Results Summary
2	Johnson and Ettinger Model Input Parameters
3	Screening-Level Indoor Air Health Risk Assessment Results (Qsoil=20 L/min and ER=1/h)
4	Screening-Level Indoor Air Health Risk Assessment Results (Qsoil=calculated and ER=2/hr)

Attachments

A	Redline Version of the Text
B	Soil Gas Data for Parcels A/B (on CD)
C	Screening-Level Indoor Air Health Risk Assessment Calculation Spreadsheets (on CD)
D	Soil Gas DVSR (on CD)
E	Data Usability Evaluation

5.0 REFERENCES

Basic Environmental Company (BEC). 2008. Technical Memorandum – Data Review for 2007 Tronox Parcels A/B Investigation, BMI Industrial Complex, Clark County, Nevada, Revision 1. February 11.

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