TECHNICAL MEMORANDUM

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Date: March 30, 2010

Subject: 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 for the Phase 2 soil gas investigation 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 and 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 and B and the soil gas sampling locations. The Technical Memorandum only presents the methods and results of the screening-level indoor air health risk assessment, and does not present investigation, data summary, data usability, or data adequacy information. This 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 Technical Memorandum, Revision 1, incorporates comments received from the NDEP, dated December 22, 2008, on Revision 0 of the report, dated November 13, 2008. The NDEP comments and BRC's response to these comments are included in Attachment A. Also included in Attachment A is a redline/strikeout version of the text showing the revisions from the November 13, 2008 version of the technical memorandum.

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. Current receptors that may use the property include on-site trespassers. Therefore, current exposures to native soils at the property are likely to be minimal. In addition, exposures to future on-site workers will be much greater than current exposures. For example, future receptors include indoor commercial workers who are assumed to be exposed to soil gas emanating from the subsurface for 250 days per year for 25 years which is much greater than any current exposures.

USEPA (1989) guidance states that potential future land use should be considered in addition to current land use when evaluating the potential for human exposure at a site. Therefore, the CSM also considers other future land-uses. For example, the CSM includes the planned use of the property for redevelopment into commercial use.

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. Although several potential human receptors may occur on the property in the future, the screening-level health risk assessment focuses on indoor commercial workers. This receptor is considered to have the highest level of exposure at the property. Other receptors generally 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.

The previous screening-level health risk assessment evaluated risks from exposure to soil. This screening-level health risk assessment is 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 USEPA does not recommend evaluating the indoor air exposure pathway using soil matrix data (USEPA 2002a). Because groundwater beneath a portion of the property is considered a potential VOC source area, soil gas data were recently collected. These data are further evaluated and are the focus of this screening-level indoor air health risk assessment.

3.0 Screening-Level Indoor Air Health Risk Assessment

As discussed above, the previous screening-level health risk assessment did not consider the indoor air pathway. Therefore, soil gas data were collected 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. The acceptable risk levels defined by USEPA for the protection of human health, and following those discussed previously with NDEP, are:

1. For non-carcinogenic compounds, the acceptable criterion is a cumulative hazard index (HI) of one or less. 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 known or suspected chemical and radionuclide carcinogens, the acceptable ceiling for a cumulative incremental lifetime cancer risk (ILCR) ranges from 10^{-6} to 10^{-4}. The risk goal established by the NDEP is 10^{-6}.

3. Where background levels exceed risk level goals, metals and radionuclides in property soils are targeted to have risks no greater than those associated with background conditions.

This screening-level indoor air health risk assessment follows the basic procedures outlined in USEPA *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (RAGS; USEPA 1989). Other guidance documents were also consulted for the screening-level indoor air health risk assessment.

<u>3.1 Selection of Chemicals of Potential Concern</u>

The broad suite of analytes sampled for was the initial list of chemicals of potential concern (COPCs) at the property. However, in order to ensure that a risk assessment focuses on those substances that contribute the greatest to the overall risk (USEPA 1989); only one procedure was used to eliminate the chemicals for quantitative evaluation in the screening-level indoor air health risk assessment: identification of chemicals that were not detected in any of the soil gas sample locations within the property.[1] That is, all chemicals that were detected in any soil gas sample within the property was considered a COPC and evaluated in the screening-level indoor air health risk assessment. The identification of those chemicals detected in soil gas samples within the property are presented in Table 1.

3.2 Determination of Exposure Point Concentrations

A representative exposure 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. Due to the uncertainty associated with determining the true average concentration at a site, where direct measurements of the site average are unavailable, the USEPA recommends using the lower of the maximum detected concentration or the 95 percent upper confidence limit (UCL) as the concentration of a chemical to which an individual could be exposed over time (USEPA 1992). For the 95 percent UCL concentration approach, the 95 percent UCL is typically computed in order to represent the area-wide exposure point concentrations. The 95 percent UCL is defined as the value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95 percent of the time (USEPA 1992). The purpose for using the 95 percent UCL is to take into account the different concentrations a person may be exposed to on any given day. That is, an individual will be exposed to a range of concentrations that exist at an exposure area, from the minimum to the maximum concentration, over an entire exposure period.

The 95 percent UCL statistical calculations were performed using the computer statistical software program GISdT® (Neptune and Company 2009). The formulas for calculating the 95 percent UCL COPC concentration (as the representative exposure concentration) are presented in USEPA (1992, 2002b). The representativeness of the 95 percent UCLs for each exposure area, that is, a property-wide mean concentration is valid since concentrations of COPCs are primarily emanating from a sub-surface groundwater source, and localized 'hot spot' concentrations within the property are not expected. Therefore each measurement is assumed to be equally representative for that chemical at any point in the property and calculation of the

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1 For those chemicals that were not detected in any of the soil gas sample locations within the property, their detection limits were compared to shallow soil gas to indoor air vapor intrusion screening levels from USEPA (2002a), Table 2b (Generic Screening Levels and Summary Sheet; Risk = 1×10^{-5}). None had detection limits that exceeded their respective screening levels. Therefore, their exclusion should not affect the results of the evaluation.

95 percent UCL is appropriate. The soil gas representative exposure concentrations used in this screening-level indoor air health risk assessment are presented in Table 1.

3.2.1 Indoor Air

The flux of COPCs from the subsurface and dispersion into indoor air were estimated using the USEPA spreadsheet-based Johnson and Ettinger model (USEPA 2004). The model is based on the vapor intrusion model published by Johnson and Ettinger (1991). The Johnson and Ettinger vapor intrusion 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). VOCs concentrations in soil gas used as representative exposure 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 Johnson and Ettinger model were used in this evaluation. These values are presented in Table 2. Table 3 presents the indoor air concentrations predicted by the Johnson and Ettinger model for each of the COPCs.

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 modeling input parameter that considers soil moisture is the water-filled porosity, which is determined by the soil moisture content and the dry bulk density. Although there is adequate soil moisture content from the site itself, 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 bulk density from the Borrow Area data of 1.83 g/cm^3 and an average soil 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 = 0.90) are used in the modeling effort for the property.

<u>3.3 Risk Assessment Methodology</u>

The method used in the screening-level indoor air health risk assessment consists of several steps. The first step is the calculation of exposure point concentrations representative of the particular 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 next 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 DBSA 2007) provides a full discussion on the risk assessment methodology for the project, and used in this screening-level indoor air health risk assessment.

Table 2 presents each of the exposure parameters used in the screening-level indoor air health risk assessment. Toxicity values, when available, are published by the USEPA in the on-line Integrated Risk Information System (IRIS; USEPA 2008) 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 2007) was used.

3.4 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 in order 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 health risk assessment 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 health risk assessment is provided below.

The screening-level indoor air health risk assessment 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. However, the sampling locations are spread across the property, and sampling was performed using approved procedures; therefore, the sampling and analysis data is sufficient to characterize the impacts and the associated potential risks.

The amount of COPCs the body absorbs may be different from the amount of a COPC contacted. In this screening-level indoor air health risk assessment, absorption of inhaled COPCs is conservatively assumed to be 100 percent. Actual chemical and site specific values are likely less than this default value.

The Johnson and Ettinger model default building characteristics assume a residential building type. However, the planned use of the property is for redevelopment into commercial use. Commercial building parameters typically result in indoor air concentrations lower than those for a residential building. For example, the recommended building air exchange rate from the California Department of Toxic Substances (DTSC; 2005) for a commercial building is 1.0 per hour versus the model default for a residential building of 0.25 per hour. This parameter alone could result in a one-fourth reduction in the indoor air concentration.

Toxicity criteria have not been established for many of the chemicals detected at the property. These chemicals were not quantitative evaluated in the screening-level indoor air health risk assessment. Thus, the risks presented in this assessment could be underestimated as a result.

The selection of exposure pathways is a process, often based on best professional judgement, which attempts to identify the most probable potentially harmful exposure scenarios. In a risk assessment it is possible that risks are not calculated for all of the exposure pathways that may occur, possibly causing some underestimation of risk. In this assessment, risks were estimated for one receptor; future on-site indoor commercial workers. Risks for the most likely route of exposure to future on-site indoor commercial workers were estimated. Specifically, risks to future on-site indoor commercial workers were estimated for inhalation of indoor air. Although it is possible that other exposure routes could exist, these exposures are expected to be lower than the risks associated with the pathway considered.

Uncertainties from different sources are compounded in the screening-level indoor air health risk assessment. 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 health risk assessment are likely to overestimate rather than underestimate potential risks.

3.5 Screening-Level Indoor Air Health Risk Assessment Results

This screening-level indoor air health risk assessment has evaluated potential risks to human health associated with chemicals detected in soil gas at the Tronox Parcels A and B property. The calculation of chemical theoretical upper-bound ILCRs and non-cancer health effects are presented in Table 4. All calculation spreadsheets for this screening-level indoor air health risk assessment are included in Attachment B.

The total cumulative non-cancer HI for future on-site indoor commercial workers at the property is 0.01, which is below the target HI of 1.0. Therefore, because the total cumulative HI is below 1.0, the potential for adverse health effects is considered unlikely.

The theoretical upper-bound ILCR for future on-site indoor commercial workers at the property is 2×10^{-6}. The risks are primarily driven by chloroform, which contributes 95 percent of the theoretical upper-bound ILCR. Although the ILCR is above the risk goal of 1×10^{-6}, it is within the acceptable risk range from 10^{-6} to 10^{-4}. Therefore, these results indicate that future receptor exposures at the property should not result in unacceptable carcinogenic risks.

4.0 Summary

Based on the results of the 2008 soil gas investigation, this data review, and the screening-level indoor air health risk assessment, concentration levels of chemicals in soil gas at the Tronox Parcels A and B property are not at levels of concern for human health risk for an indoor commercial scenario. In addition, the screening-level health risk assessment is 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). Based on the results of the 2007 investigation and the 2008 screening-level health risk assessment, concentration levels of chemicals at the Tronox Parcels A and B property are not at levels of concern for human health risk for an industrial scenario. BEC concluded, and NDEP concurred, that an NFAD for the property was warranted.

A quantitative summing of the risks associated with the 2008 screening-level health risk assessment and this current screening-level indoor air health risk assessment is considered inappropriate given their differing methodologies; however, qualitatively the risks for both risk assessments combined would be less than an HI of 1.0 for non-carcinogens and the theoretical upper-bound ILCR would be within the acceptable risk range for carcinogens. Therefore, BEC concludes that an NFAD for the property is further supported by these results.

5.0 REFERENCES

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Attachments: Figure 1 – Tronox Parcels A/B Phase B Soil Gas Sample Locations
Table 1 – Chemicals of Potential Concern and Representative Exposure Concentrations in Soil Gas
Table 2 – Johnson and Ettinger Model Input Parameters
Table 3 – Model Estimated Indoor Air Concentrations
Table 4 –Screening-Level Indoor Air Health Risk Assessment Results
Attachment A – Tronox/BEC Response to Comments and Redline Version of the Text
Attachment B – Screening-Level Indoor Air Health Risk Assessment Calculation Spreadsheets (on CD)

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all applicable federal, state and local statutes, regulations and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

March 30, 2010

Dr. Ranajit Sahu, C.E.M. (No. EM-1699, Exp. 10/07/2011) Date
BRC Project Manager

FIGURES

Tronox Parcels A/B Boundary

Soil Gas Sample Locations

- Location within Parcels A/B
- Other Sample Location

BEC / Tronox Parcels A/B Data Review
BMI Common Areas, Henderson, Nevada

FIGURE 1

TRONOX PARCELS A/B
PHASE B SOIL GAS
SAMPLE LOCATIONS

Basic Environmental COMPANY

Prepared by: MKJ	Date 03/25/10	JOB No. 0069073 FILE: GIS/BEC/TRONOX_AB/FIGURE_1.MXD

TABLES

TABLE 1
CHEMICALS OF POTENTIAL CONCERN AND REPRESENTATIVE EXPOSURE CONCENTRATIONS IN SOIL GAS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA

Chemical	Number of Samples	Number of Detections	Frequency of Detects	Minimum DL	Maximum DL	Minimum Detection	Median[a]	Mean[a]	Maximum Detection	95% UCL	EPC
1,1,1-Trichloroethane	9	0	0%	0.15	0.17	--	0.080	0.079	--	--	--
1,1,2,2-Tetrachloroethane	9	0	0%	0.15	0.17	--	0.080	0.079	--	--	--
1,1,2-Trichloroethane	9	1	11%	0.15	0.17	0.12	0.080	0.083	0.12	0.093	0.093
1,1,2-Trichlorotrifluoroethane	9	9	100%	--	--	0.45	0.49	0.50	0.63	0.55	0.55
1,1-Dichloroethane	9	7	78%	0.15	0.16	0.11	0.41	8.0	27	16	16
1,1-Dichloroethene	9	2	22%	0.15	0.17	0.10	0.080	0.086	0.12	0.097	0.097
1,2,4-Trichlorobenzene	9	3	33%	0.15	0.17	0.20	0.080	0.21	0.75	0.37	0.37
1,2,4-Trimethylbenzene	9	9	100%	--	--	0.12	0.37	0.87	3.5	1.8	1.8
1,2-Dibromo-3-chloropropane	9	0	0%	0.74	0.85	--	0.39	0.4	--	--	--
1,2-Dichlorobenzene	9	0	0%	0.15	0.17	--	0.080	0.079	--	--	--
1,2-Dichloroethane	9	3	33%	0.15	0.16	0.32	0.080	0.27	1.1	0.56	0.56
1,2-Dichloropropane	9	4	44%	0.15	0.17	0.085	0.085	0.13	0.47	0.25	0.25
1,2-Dichlorotetrafluoroethane	9	5	56%	0.77	0.85	0.085	0.10	0.23	0.10	0.33	0.1
1,3,5-Trimethylbenzene	9	5	56%	0.77	0.85	0.090	0.39	0.49	1.9	0.99	0.99
1,3-Dichlorobenzene	9	3	33%	0.15	0.17	0.098	0.085	0.12	0.32	0.19	0.19
1,4-Dichlorobenzene	9	9	100%	--	--	0.31	0.84	8.0	43	21	21
1,4-Dioxane	9	5	56%	0.77	0.85	0.14	0.39	0.29	0.39	0.37	0.37
2-Butanone	9	9	100%	--	--	4.6	7.0	7.3	13	9.1	9.1
2-Hexanone	9	9	100%	--	--	0.26	0.43	0.42	0.52	0.46	0.46
2-Methoxy-2-methyl-butane	9	0	0%	0.74	0.85	--	0.39	0.40	--	--	--
4-Ethyltoluene	9	6	67%	0.77	0.85	0.11	0.39	0.41	1.5	0.77	0.77
4-Isopropyltoluene	9	7	78%	0.77	0.85	0.13	0.39	0.80	4.4	1.8	1.8
4-Methyl-2-pentanone	9	9	100%	--	--	0.14	0.29	1.3	9.2	4.2	4.2
Acetone	9	7	78%	15	24	12	18	21	50	31	31
Acrylonitrile	9	3	33%	0.77	0.85	0.11	0.39	0.31	0.12	0.40	0.12
Allyl chloride	9	1	11%	0.15	0.17	0.17	0.080	0.089	0.17	0.11	0.11
alpha-Methylstyrene	9	4	44%	0.74	0.85	0.13	0.39	1.1	7.7	3.6	3.6
Benzene	9	9	100%	--	--	1.2	1.9	1.9	2.7	2.2	2.2
Benzyl Chloride	9	0	0%	0.15	0.17	--	0.080	0.079	--	--	--
Bromodichloromethane	9	6	67%	0.16	0.17	0.098	0.18	0.22	0.67	0.38	0.38
Bromoform	9	1	11%	0.74	0.85	0.27	0.39	0.39	0.27	0.41	0.27
Bromomethane	9	1	11%	0.15	0.17	0.11	0.080	0.082	0.11	0.091	0.091
Carbon disulfide	9	7	78%	1.1	1.4	1.5	2.0	4.9	14	8.2	8.2

TABLE 1
CHEMICALS OF POTENTIAL CONCERN AND REPRESENTATIVE EXPOSURE CONCENTRATIONS IN SOIL GAS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA

Chemical	Number of Samples	Number of Detections	Frequency of Detects	Minimum DL	Maximum DL	Minimum Detection	Median[a]	Mean[a]	Maximum Detection	95% UCL	EPC
Carbon tetrachloride	9	9	100%	--	--	0.25	0.39	3.0	11	5.8	5.8
Chlorobenzene	9	3	33%	0.15	0.17	0.16	0.080	0.12	0.31	0.18	0.18
Chloroethane	9	7	78%	0.15	0.16	0.14	0.87	3.1	11	5.9	5.9
Chloroform	9	9	100%	--	--	8.6	34	140	440	260	260
Chloromethane	9	1	11%	0.15	0.17	0.076	0.080	0.079	0.076	0.082	0.076
cis-1,2-Dichloroethene	9	2	22%	0.15	0.17	0.15	0.080	1.5	13	5.8	5.8
cis-1,3-Dichloropropene	9	0	0%	0.74	0.85	--	0.39	0.40	--	--	--
Dibromochloromethane	9	1	11%	0.15	0.17	0.12	0.080	0.084	0.12	0.094	0.094
Dichlorodifluoromethane	9	9	100%	--	--	1.8	2.0	2.0	2.1	2.1	2.1
Ethanol	9	9	100%	--	--	2.3	11	14	32	21	21
Ethyl t-butyl ether	9	0	0%	0.74	0.85	--	0.39	0.40	--	--	--
Ethylbenzene	9	7	78%	0.77	0.85	0.10	0.39	0.44	1.2	0.70	0.70
Ethylene dibromide	9	0	0%	0.15	0.17	--	0.080	0.079	--	--	--
Hexachlorobutadiene	9	5	56%	0.15	0.17	0.49	0.49	0.66	2.4	1.2	1.2
isopropyl ether	9	0	0%	0.74	0.85	--	0.39	0.40	--	--	--
Isopropylbenzene	9	3	33%	0.74	0.85	0.088	0.39	0.31	0.19	0.40	0.19
m,p-Xylene	9	8	89%	0.77	0.77	0.22	0.80	1.4	5.9	2.8	2.8
Methyl methacrylate	9	1	11%	0.74	0.85	0.42	0.39	0.40	0.42	0.41	0.41
Methyl tert butyl ether	9	6	67%	0.15	0.16	0.10	0.33	1.4	7.8	3.7	3.7
Methylene chloride	9	8	89%	0.77	0.77	0.23	0.63	1.2	3.7	2.0	2.0
Naphthalene	9	9	100%	--	--	0.42	0.83	1.2	4.2	2.1	2.1
N-Butylbenzene	9	9	100%	--	--	0.12	0.26	0.31	0.68	0.44	0.44
n-Heptane	9	6	67%	0.77	0.85	0.24	0.43	0.42	0.72	0.52	0.52
n-Octane	9	4	44%	0.77	0.85	0.23	0.39	0.49	1.5	0.86	0.86
N-Propylbenzene	9	5	56%	0.77	0.85	0.084	0.39	0.31	0.52	0.41	0.41
o-Xylene	9	7	78%	0.77	0.85	0.12	0.42	0.61	2.1	1.1	1.1
sec-Butylbenzene	9	1	11%	0.74	0.85	0.097	0.39	0.36	0.097	0.43	0.10
Styrene	9	5	56%	0.77	0.85	0.16	0.39	0.38	0.6	0.45	0.45
t-Butyl alcohol	9	9	100%	--	--	0.20	0.45	0.44	0.67	0.53	0.53
tert-Butylbenzene	9	1	11%	0.29	0.34	0.14	0.16	0.16	0.14	0.16	0.14
Tetrachloroethene	9	9	100%	--	--	1.1	5.3	7.4	30	14	14
Toluene	9	9	100%	--	--	1.2	2.0	4.4	19	9.8	9.8
trans-1,2-Dichloroethylene	9	0	0%	0.15	0.17	--	0.08	0.079	--	--	--

TABLE 1
CHEMICALS OF POTENTIAL CONCERN AND REPRESENTATIVE EXPOSURE CONCENTRATIONS IN SOIL GAS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA

Chemical	Number of Samples	Number of Detections	Frequency of Detects	Minimum DL	Maximum DL	Minimum Detection	Median[a]	Mean[a]	Maximum Detection	95% UCL	EPC
trans-1,3-Dichloropropene	9	0	0%	0.74	0.85	--	0.39	0.40	--	--	--
Trichloroethene	9	9	100%	--	--	0.96	1.3	6.5	42	19	19
Trichlorofluoromethane	9	9	100%	--	--	0.95	1.1	1.1	1.4	1.2	1.2
Vinyl acetate	9	7	78%	7.7	7.8	0.99	3.5	3.4	5.0	4.2	4.2
Vinyl chloride	9	2	22%	0.15	0.16	0.12	0.080	0.087	0.12	0.099	0.099

Note: All units in $\mu g/m^3$.
a - Includes both detect values and non-detect values, with one-half the DL used for non-detect values.
DL = detection limit
UCL = upper confidence limit
EPC = exposure point concentration
-- = Not applicable or statistic not evaluated because all results were non-detect..

TABLE 2
JOHNSON AND ETTINGER MODEL INPUT PARAMETERS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA
(Page 1 of 1)

Parameter	Value	Reference/Rationale
Depth below grade to bottom of enclosed floor space (cm)	15	Model default (slab on grade)
Average soil temperature (°C)	15	Model default
Soil gas sampling depth (cm)	200	Site-specific (five feet bgs)
Thickness of soil stratum (cm)	200	Site-specific (five feet bgs)
Soil stratum used to calculate soil vapor permeability	S	Sand
Vadose zone dry bulk density (g/cm^3)	1.83	Site-specific (Borrow Area data)
Vadose zone total porosity (unitless)	0.30	Site-specific (Borrow Area data)
Soil moisture content (unitless)	0.049	Site-specific
Vadose zone water-filled porosity (unitless)	0.090	Bulk density × soil moisture
Enclosed space floor thickness (cm)	15	Model default
Soil-building pressure differential ($g/cm\text{-}s^2$)	40	Model default
Enclosed space floor length (cm)	1,000	Model default
Enclosed space floor width (cm)	1,000	Model default
Modeling Enclosed space height (cm)	244	Model default
Floor-wall seam crack width (cm)	0.1	Model default
Average vapor flow rate into building, Qsoil (L/m)	5	Model default
Indoor air exchange rate (1/hr)	0.25	Model default
Exposure duration (yrs)	25	USEPA 2002
Exposure frequency (days/yr)	250	USEPA 2002
Averaging time for carcinogens (yrs)	70	USEPA 2002
Averaging time for non-carcinogens (yrs)	25	USEPA 2002

TABLE 3
MODEL ESTIMATED INDOOR AIR CONCENTRATIONS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA
(Page 1 of 2)

Chemical	Predicted Indoor Air Concentration ($\mu g/m^3$)[1]
1,1,2-Trichloroethane	1.1 E-4
1,1,2-Trichlorotrifluoroethane	6.4 E-4
1,1-Dichloroethane	1.8 E-2
1,1-Dichloroethene	1.3 E-4
1,2,4-Trichlorobenzene	1.9 E-4
1,2,4-Trimethylbenzene	1.7 E-3
1,2-Dichloroethane	8.0 E-4
1,2-Dichloropropane	3.0 E-4
1,2-Dichlorotetrafluoroethane	1.2 E-4
1,3,5-Trimethylbenzene	9.5 E-4
1,3-Dichlorobenzene	2.0 E-4
1,4-Dichlorobenzene	2.2 E-2
1,4-Dioxane	5.3 E-4
2-Butanone	1.1 E-2
2-Hexanone	1.0 E-3
4-Ethyltoluene	9.7 E-4
4-Isopropyltoluene	1.6 E-3
4-Methyl-2-pentanone	4.8 E-3
Acetone	5.0 E-2
Acrylonitrile	1.9 E-4
Allyl chloride	1.7 E-4
alpha-Methylstyrene	9.0 E-3
Benzene	2.8 E-3
Bromodichloromethane	2.0 E-4
Bromoform	7.5 E-5
Bromomethane	1.0 E-4
Carbon disulfide	1.2 E-2
Carbon tetrachloride	6.8 E-3
Chlorobenzene	1.9 E-4
Chloroethane	1.5 E-2
Chloroform	3.7 E-1
Chloromethane	1.3 E-4
cis-1,2-Dichloroethene	6.5 E-3
Dibromochloromethane	3.4 E-5
Dichlorodifluoromethane	2.1 E-3
Ethanol	3.4 E-2
Ethylbenzene	8.0 E-4
Hexachlorobutadiene	1.0 E-3
Isopropylbenzene	1.9 E-4
m,p-Xylene	3.0 E-3
Methyl methacrylate	4.8 E-4
Methyl tert butyl ether	5.3 E-3
Methylene chloride	2.8 E-3
Naphthalene	2.0 E-3
N-Butylbenzene	4.0 E-4
n-Heptane	1.1 E-3
n-Octane	9.9 E-4
N-Propylbenzene	3.9 E-4
o-Xylene	1.4 E-3

TABLE 3
MODEL ESTIMATED INDOOR AIR CONCENTRATIONS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA

Chemical	Predicted Indoor Air Concentration ($\mu g/m^3$)[1]
sec-Butylbenzene	8.9 E-5
Styrene	4.9 E-4
t-Butyl alcohol	7.0 E-4
tert-Butylbenzene	1.3 E-4
Tetrachloroethene	1.5 E-2
Toluene	1.7 E-2
Trichloroethene	2.3 E-2
Trichlorofluoromethane	1.5 E-3
Vinyl acetate	5.2 E-3
Vinyl chloride	1.4 E-4

[1] - Calculated using the J&E Model (included on CD).

TABLE 4
SCREENING-LEVEL INDOOR AIR HEALTH RISK ASSESSMENT RESULTS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA

Chemical	Non-Cancer Reference Concentration (mg/kg-d)	Unit Risk Factor $(mg/kg\text{-}d)^{-1}$	J&E Predicted Conc.[a]	Non-Cancer Hazard Index	Incremental Lifetime Cancer Risk
1,1,2-Trichloroethane	1.6 E-5	1.4 E-2	1.1 E-4	0.00001	4 E-10
1,1,2-Trichlorotrifluoroethane	NA	3.0 E+1	6.4 E-4	0.00000001	NA
1,1-Dichloroethane	NA	7.0 E-1	1.8 E-2	0.00002	NA
1,1-Dichloroethene	NA	2.0 E-1	1.3 E-4	0.0000004	NA
1,2,4-Trichlorobenzene	NA	4.0 E-3	1.9 E-4	0.00003	NA
1,2,4-Trimethylbenzene	NA	7.0 E-3	1.7 E-3	0.0002	NA
1,2-Dichloroethane	2.6 E-5	4.9 E-3	8.0 E-4	0.0001	5 E-9
1,2-Dichloropropane	1.9 E-5	4.0 E-3	3.0 E-4	0.0001	1 E-9
1,2-Dichlorotetrafluoroethane	NA	NA	1.2 E-4	NA	NA
1,3,5-Trimethylbenzene	NA	6.0 E-3	9.5 E-4	0.0001	NA
1,3-Dichlorobenzene	NA	8.0 E-3	2.0 E-4	0.00002	NA
1,4-Dichlorobenzene	6.9 E-6	8.0 E-1	2.2 E-2	0.00002	4 E-8
1,4-Dioxane	3.1 E-6	NA	5.3 E-4	NA	4 E-10
2-Butanone	NA	5.0 E+0	1.1 E-2	0.000001	NA
2-Hexanone	NA	NA	1.0 E-3	NA	NA
4-Ethyltoluene	NA	NA	9.7 E-4	NA	NA
4-Isopropyltoluene	NA	NA	1.6 E-3	NA	NA
4-Methyl-2-pentanone	NA	3.0 E+0	4.8 E-3	0.000001	NA
Acetone	NA	3.2 E+0	5.0 E-2	0.00001	NA
Acrylonitrile	6.8 E-5	2.0 E-3	1.9 E-4	0.0001	3 E-9
Allyl chloride	NA	1.0 E-3	1.7 E-4	0.0001	NA
alpha-Methylstyrene	NA	4.0 E-2	9.0 E-3	0.0002	NA
Benzene	7.8 E-6	3.0 E-2	2.8 E-3	0.0001	5 E-9
Bromodichloromethane	1.8 E-5	7.0 E-2	2.0 E-4	0.000002	9 E-10
Bromoform	1.1 E-6	7.0 E-2	7.5 E-5	0.000001	2 E-11
Bromomethane	NA	5.0 E-3	1.0 E-4	0.00001	NA
Carbon disulfide	NA	7.0 E-1	1.2 E-2	0.00001	NA
Carbon tetrachloride	1.5 E-5	NA	6.8 E-3	NA	2 E-8
Chlorobenzene	NA	5.0 E-2	1.9 E-4	0.000003	NA
Chloroethane	8.3 E-7	1.0 E+1	1.5 E-2	0.000001	3 E-9
Chloroform	2.3 E-5	4.5 E-2	3.7 E-1	0.01	2 E-6
Chloromethane	NA	9.0 E-2	1.3 E-4	0.000001	NA
cis-1,2-Dichloroethene	NA	3.5 E-2	6.5 E-3	0.0001	NA
Dibromochloromethane	2.4 E-5	7.0 E-2	3.4 E-5	0.0000003	2 E-10
Dichlorodifluoromethane	NA	2.0 E-1	2.1 E-3	0.00001	NA
Ethanol	NA	NA	3.4 E-2	NA	NA
Ethylbenzene	NA	1.0 E+0	8.0 E-4	0.000001	NA
Hexachlorobutadiene	2.2 E-5	NA	1.0 E-3	NA	6 E-9
Isopropylbenzene	NA	4.0 E-1	1.9 E-4	0.0000003	NA
m,p-Xylene	NA	1.0 E-1	3.0 E-3	0.00002	NA
Methyl methacrylate	NA	7.0 E-1	4.8 E-4	0.0000005	NA
Methyl tert butyl ether	NA	3.0 E+0	5.3 E-3	0.000001	NA
Methylene chloride	4.7 E-7	3.0 E+0	2.8 E-3	0.000001	3 E-10
Naphthalene	NA	3.0 E-3	2.0 E-3	0.0004	NA
N-Butylbenzene	NA	1.4 E-1	4.0 E-4	0.000002	NA
n-Heptane	NA	NA	1.1 E-3	NA	NA
n-Octane	NA	NA	9.9 E-4	NA	NA
N-Propylbenzene	NA	1.4 E-1	3.9 E-4	0.000002	NA
o-Xylene	NA	1.0 E-1	1.4 E-3	0.00001	NA

TABLE 4
SCREENING-LEVEL INDOOR AIR HEALTH RISK ASSESSMENT RESULTS
TRONOX PARCELS A/B SOIL GAS INVESTIGATION
CLARK COUNTY, NEVADA
(Page 2 of 2)

Chemical	Non-Cancer Reference Concentration (mg/kg-d)	Unit Risk Factor $(mg/kg\text{-}d)^{-1}$	J&E Predicted Conc.[a]	Non-Cancer Hazard Index	Incremental Lifetime Cancer Risk
sec-Butylbenzene	NA	1.4 E-1	8.9 E-5	0.0000004	NA
Styrene	NA	1.0 E+0	4.9 E-4	0.0000003	NA
t-Butyl alcohol	NA	NA	7.0 E-4	NA	NA
tert-Butylbenzene	NA	1.4 E-1	1.3 E-4	0.000001	NA
Tetrachloroethene	5.9 E-6	6.0 E-1	1.5 E-2	0.00002	2 E-8
Toluene	NA	5.0 E+0	1.7 E-2	0.000002	NA
Trichloroethene	1.1 E-4	4.0 E-2	2.3 E-2	0.000002	NA
Trichlorofluoromethane	NA	7.0 E-1	1.5 E-3	0.000002	NA
Vinyl acetate	NA	2.0 E-1	5.2 E-3	0.00002	NA
Vinyl chloride	4.4 E-6	1.0 E-1	1.4 E-4	0.000001	2 E-10
			Total	0.01	2 E-6

[a]From Table 3; concentration is in $\mu g/m^3$.

NA - Toxicity criteria has not been established.

ATTACHMENT A

TRONOX/BEC RESPONSE TO COMMENTS
AND REDLINE VERSION OF THE TEXT

Attachment A
Response to NDEP Comments Dated December 22, 2008 on the Technical Memorandum – Screening-Level Indoor Air Health Risk Assessment for the 2008 Tronox Parcels A/B Soil Gas Investigation Dated November 13, 2008

This Response to Comments has been Prepared by BEC on Behalf of Tronox

1. General comments, the NDEP has the following general comments regarding the subject document:
   a. The subject document in general and the CSM in particular make no reference to the Phase 2 Investigation on Parcels A and B.

Response: *Reference to the Technical Memorandum – Data Review for 2007 Tronox Parcels A/B Investigation has been provided in the revise document on pages 1 and 2. In addition, a summary of the Screening-Level Risk Assessment Results from this document has also been added on page 9.*

   b. Shallow soil samples have been collected at other locations at the BMI Industrial Complex and analyzed for physical properties. BRC should explore how the default Johnson and Ettinger (J&E) model values compare to the data collected either on Parcels A & B or in the general area. For the soil gas calculations particular attention should be paid to the soil moisture content.

Response: *The default modeling 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 site should be considered a conservative estimate of potential indoor air risks. The modeling input parameter that considers soil moisture is the water-filled porosity, which is determined by the soil moisture content and the dry bulk density. Although there is adequate soil moisture content from the site itself, there is limited dry bulk density data for the general area; however, this information is available from the Borrow Area investigation. Using an average bulk density from the Borrow Area data of 1.83 g/cm3 and an average soil 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; total porosity = 0.30; water-filled porosity = 0.90) have been used in the revised document.*

   c. The subject document does not adequately describe the modeling work that was performed.

Response: *Additional discussion on the model has been added on page 5.*

   d. The NDEP's review of the subject document would be aided by the addition of Section numbers.

Response: *Section numbers have been added to the revised report.*

e. It appears that the data used in this assessment may have been reported with non-detects shown at their reporting limits rather than their detection limits. For example, for 1,1,2-TCA there are eight non-detects reported between 0.15 ug/m3 and 0.17 ug/m3. There is one detected value reported with a J flag at 0.12 ug/m3. Looking through the remainder of the dataset (beyond the nine samples used in these analyses), it appears that detects are quite often reported below the non-detect levels. This is usually an indication that the non-detects are being reported at a reporting limit rather than a method or instrument detection limit. That practice causes substantial overestimation of concentrations when the frequency of detection is low.

Response: *Agreed. Because this is a screening-level evaluation, no changes have been made in response to this comment, but it is acknowledged that this adds to the conservativeness of the results of the indoor air health risk assessment.*

2. Introduction, page 1, the data validation summary report (DVSR) for the soil gas should be appropriately referenced. In addition, all referenced reports should denote their approval status.

Response: *Reference to the Tronox DVSR has been provided.*

3. Selection of Chemicals of Potential Concern, page 3, all chemicals that were not detected in soil gas at the site were eliminated from further consideration. This is an acceptable approach when it is accompanied by some consideration of whether reasonable detection limits were achieved for such chemicals. Without that information it is impossible to know if it is acceptable to eliminate those chemicals. This information may be in the DVSR that is referenced in the Introduction, if so, that is adequate, however, so additional explanation would be helpful. Please clarify.

Response: *A discussion on detection limits and their effective on the selection of chemicals of potential concern has been added as a footnote on page 4. Specifically, detection limits for chemicals eliminated as COPCs were compared to USEPA soil gas screening levels.*

4. Determination of Exposure Point Concentrations, pages 3 through 5
   a. Please note that the United States Environmental Protection Agency (USEPA) actually encourages that both a central tendency estimate (CTE) and a reasonable maximum estimate (RME) be used to help account for the uncertainties associated with determining risk. It is fine in this case for TRX to use only an RME, but the wording of this paragraph is a bit confusing.

Response: *The section in question presents a standard discussion on the use of the 95 percent UCL as the representative exposure concentration. We are unclear on what the confusion is regarding this issue.*

b. Indoor Air, page 4, TRX states "Maximum detected VOCs concentrations in soil gas were used as representative exposure concentrations for the indoor air exposure pathway." The J&E spreadsheet calculations used the 95 percent UCL values not the maximum. This inconsistency needs to be rectified.

Response: *This sentence has been revised on page 5.*

a. Page 4, 1st paragraph, in the final sentence, "non-detect" isn't quite the right term to use. NDEP suggests that TRX use the term "minimum" in place of "non-detect".

Response: *This sentence has been revised on page 4.*

5. Uncertainty Analysis, page 5, the NDEP has the following comments:
   a. TRX states "The environmental sampling at the property is one source of uncertainty in the evaluation. However, the number of sampling locations and events is large and widespread…" Please note that nine samples within Parcels A and B would not be considered "large", however, this may be "adequate".

Response: *This sentence has been revised on page 7.*

   b. The uncertainty analysis should discuss the fact the screening level indoor risk assessment used default values for a residential scenario while the assessment was intended for a commercial use scenario.3

Response: *A paragraph has been added on page 7 addressing this issue.*

6. Screening-Level Indoor Air Health Risk Assessment Results and Summary, page 7, the results of the previous screening-level health risk assessment for Parcels A and B should be mentioned in this summary. The soil gas assessment for indoor air was intended to fill a gap in that assessment. These results on their own, without combining the potentially additive risks, do not provide an adequate assessment of the potential risks to a commercial worker on this site.

Response: *Because of how each of the two separate risk assessments were conducted—that is, this risk assessment uses the calculation of a 95 percent UCL and calculated risk estimates based on unit risk factors and reference concentrations, whereas, the previous risk assessment was conducted based on a ratio to screening levels approach—a summation of these separate risk results is considered inappropriate. However, a discussion on the previous results, and what these new risks mean in relation to these previous risks has been added on page 9.*

7. Table 1, TRX needs to review this table for issues with significant figures.

a. Upon close inspection, the main issue seems only to occur with trailing zeros. For example, the data are presented with two significant digits, but 8.0 is shown as 8, and .50 is shown as .5.
b. NDEP also notes that three significant figures were reported for some medians (e.g., 1,4-Dioxane) although the reported value in the data files contains only two significant figures (0.39 in the data file and 0.385 in Table 1).
c. Finally, another case where three significant figures were used was for the Chloroform UCL, which should clearly only have two significant figures since it is calculated from data that contain only two significant figures.

Response: *Because the results are generally presented to two significant figures, all values in Table 1 have been revised to two significant figures.*

8. Table 2, the NDEP has the following comments:
a. Please note that average soil temperature is not intended to be a default value.
i. The average soil temperature of 10°C appears low for Las Vegas which has a mean annual temperature of approximately 20°C.

Response: *According to the Fact Sheet for Correcting the Henry's Law Constant for Temperature (obtained from http://epa.gov/swerrims/riskassessment/airmodel/ johnson_ettinger.htm), "For depths greater than 100 cm, the mean annual soil temperature remains relatively stable throughout the year and can be estimated from the average shallow ground water temperatures shown in Figure 1." Figure 1 indicates that the average shallow ground water temperature for Las Vegas is from 57°F to 62°F, or 13.9°C to 16.7°C. Therefore, the model has been adjusted to use an average soil temperature of 15°C.*

b. Was the soil type used (sand) based on site-specific data? There are no text references in this regard.
i. The NDEP is accepts the default soil physical properties provided the soil type is site-specific.

Response: *A sand soil type was selected because it provides the most conservative estimate of indoor air concentrations. However, as indicated in response to comment 1b, default values have been adjusted with site-specific values were available.*

c. Exposure duration, exposure frequency, and averaging time for non-carcinogens values employed are not J&E Model default values.

Response: *Agreed. The reference/rationale has been changed on this table for these parameters.*

9. Table 4, several of the chemical names were truncated.

Response: *The 'Chemical' column width has been adjusted.*

10. J&E Model Spreadsheets
    a. Chemical Properties Lookup Table, Vlookup Tab. References were not provided for updated information and for the chemicals added to the table.

Response: *The chemical properties were provided from either the Hazardous Substances Databank (HSDB) website (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB) or EPA's Water 9 v.3 software.*

    b. DataEnter sheets were provided even when the chemical was non-detect (ND) in all nine samples. Chemical Group 1, for example, includes input sheets1,1,1-TCA and 1,2-DCB but the chemicals were not detected.

Response: *The DataEnter sheets have been adjusted to only include COPCs.*

    c. J&E model calculations were checked for one chemical from each of the four chemical groups as follows:
        i. Group 1 – 1,4-DCB
        ii. Group 2 – benzene
        iii. Group 3 – chloroform
        iv. Group 4 – PCE
        v. NDEP comments are provided below for each of these compounds.
    d. Group 1
        i. DataEnter 1,4-Dioxane – the CAS number appears correct but the chemical reported at I12 (spreadsheet location) is Crotonaldehyde (2-butenal)? The problem is that TRX added chemicals to the Chemical Properties Lookup Table; but did not sort the table (lowest to highest CAS number). Hence the VLOOKUP formula in cell I12 does not work properly in the files provided. This problem can be solved in one of two ways:
            1. Simply sort the VLOOKUP table in ascending order after adding new chemicals to the list, or
            2. Modify the formula in cell I12 as follows by adding argument FALSE (highlighted yellow): IF(ISERROR(MATCH(E12,CAS_No,0)),"CAS No. not found",VLOOKUP(E12,Chemical_Data,2,FALSE))
                a. By adding this argument the table need not be in ascending order.
        ii. The NDEP sorted the VLOOKUP table and the formula worked properly.
            1. This operation was performed for the VLOOKUP table for each of the four chemical groups
        iii. Various factors (e.g., RfC and URF) were updated but no references for this information were provided.
    e. Groups 2 through 4
        i. This set of spreadsheets contains the same error as noted above.
        ii. Various factors (e.g., RfC and URF) were updated but no references for this information were provided.

Response: *The tables have been adjusted as suggested by this comment. It should be noted that this does not affect the model results as the calculations are based on lookup's off of the CAS number*.

REDLINE/STRIKE-OUT TEXT

TECHNICAL MEMORANDUM

To: Shannon Harbour (NDEP)

From: Ranajit Sahu (BEC)

cc: Brian Rakvica (NDEP)
Jim Najima (NDEP)
Teri Copeland
Paul Black (Neptune and Co.)

Date: March 30, 2010~~November 3, 2008~~

Subject: 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 for the Phase 2 soil gas investigation 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 and 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 and B and the soil gas sampling locations. The Technical Memorandum only presents the methods and results of the screening-level indoor air health risk assessment, and does not present investigation, data summary, data usability~~usabilty~~, or data adequacy information. This 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 Technical Memorandum, Revision 1, incorporates comments received from the NDEP, dated December 22, 2008, on Revision 0 of the report, dated November 13, 2008. The NDEP comments and BRC's response to these comments are included in Attachment A. Also included in Attachment A is a redline/strikeout version of the text showing the revisions from the November 13, 2008 version of the technical memorandum.

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. Current receptors that may use the property include on-site trespassers. Therefore, current exposures to native soils at the property are likely to be minimal. In addition, exposures to future on-site workers will be much greater than current exposures. For example, future receptors include indoor commercial workers who are assumed to be exposed to soil gas emanating from the subsurface for 250 days per year for 25 years which is much greater than any current exposures.

USEPA (1989) guidance states that potential future land use should be considered in addition to current land use when evaluating the potential for human exposure at a site. Therefore, the CSM also considers other future land-uses. For example, the CSM includes the planned use of the property for redevelopment into commercial use.

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. Although several potential human receptors may occur on the property in the future, the screening-level health risk assessment focuses on indoor commercial workers. This receptor is considered to have the highest level of exposure at the property. Other receptors generally 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.

The previous screening-level health risk assessment evaluated risks from exposure to soil. This screening-level health risk assessment is 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 USEPA does not recommend evaluating the indoor air exposure pathway using soil matrix data (USEPA 2002a). Because groundwater beneath a portion of the property is considered a potential VOC source area, soil gas data were recently collected. These data are further evaluated and are the focus of this screening-level indoor air health risk assessment.

3.0 Screening-Level Indoor Air Health Risk Assessment

As discussed above, the previous screening-level health risk assessment did not consider the indoor air pathway. Therefore, soil gas data were collected 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. The acceptable risk levels defined by USEPA for the protection of human health, and following those discussed previously with NDEP, are:

1. For non-carcinogenic compounds, the acceptable criterion is a cumulative hazard index (HI) of one or less. 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 known or suspected chemical and radionuclide carcinogens, the acceptable ceiling for a cumulative incremental lifetime cancer risk (ILCR) ranges from 10^{-6} to 10^{-4}. The risk goal established by the NDEP is 10^{-6}.

3. Where background levels exceed risk level goals, metals and radionuclides in property soils are targeted to have risks no greater than those associated with background conditions.

This screening-level indoor air health risk assessment follows the basic procedures outlined in USEPA *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* (RAGS; USEPA 1989). Other guidance documents were also consulted for the screening-level indoor air health risk assessment.

3.1 Selection of Chemicals of Potential Concern

The broad suite of analytes sampled for was the initial list of chemicals of potential concern (COPCs) at the property. However, in order to ensure that a risk assessment focuses on those substances that contribute the greatest to the overall risk (USEPA 1989); only one procedure was used to eliminate the chemicals for quantitative evaluation in the screening-level indoor air health risk assessment: identification of chemicals that were not detected in any of the soil gas sample locations within the property.[1] That is, all chemicals that were detected in any soil gas sample within the property was considered a COPC and evaluated in the screening-level indoor air health risk assessment. The identification of those chemicals detected in soil gas samples within the property are presented in Table 1.

3.2 Determination of Exposure Point Concentrations

A representative exposure 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. Due to the uncertainty associated with determining the true average concentration at a site, where direct measurements of the site average are unavailable, the USEPA recommends using the lower of the maximum detected concentration or the 95 percent upper confidence limit (UCL) as the concentration of a chemical to which an individual could be exposed over time (USEPA 1992). For the 95 percent UCL concentration approach, the 95 percent UCL is typically computed in order to represent the area-wide exposure point concentrations. The 95 percent UCL is defined as the value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95 percent of the time (USEPA 1992). The purpose for using the 95 percent UCL is to take into account the different concentrations a person may be exposed to on any given day. That is, an individual will be exposed to a range of concentrations that exist at an exposure area, from the minimumnon-detect to the maximum concentration, over an entire exposure period.

The 95 percent UCL statistical calculations were performed using the computer statistical software program GISdT® (Neptune and Company 20092007). The formulas for calculating the 95 percent UCL COPC concentration (as the representative exposure concentration) are presented in USEPA (1992, 2002b). The representativeness of the 95 percent UCLs for each exposure area, that is, a property-wide mean concentration is valid since concentrations of COPCs are primarily emanating from a sub-surface groundwater source, and localized 'hot spot' concentrations within the property are not expected. Therefore each measurement is assumed to be equally representative for that chemical at any point in the property and calculation of the 95 percent UCL is appropriate. The soil gas representative exposure

[1] For those chemicals that were not detected in any of the soil gas sample locations within the property, their detection limits were compared to shallow soil gas to indoor air vapor intrusion screening levels from USEPA (2002a), Table 2b (Generic Screening Levels and Summary Sheet; Risk = 1×10^{-5}). None had detection limits that exceeded their respective screening levels. Therefore, their exclusion should not affect the results of the evaluation.

concentrations used in this screening-level indoor air health risk assessment are presented in Table 1.

3.2.1 Indoor Air

The flux of COPCs from the subsurface and dispersion into indoor air were estimated using the USEPA spreadsheet-based Johnson and Ettinger model (USEPA 2004). The model is based on the vapor intrusion model published by Johnson and Ettinger (1991). The Johnson and Ettinger vapor intrusion 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). ~~Maximum detected~~ VOCs concentrations in soil gas ~~were~~ used as representative exposure concentrations for the indoor air exposure pathway are presented in Table 1. Either site-specific or ~~. The~~ default physical properties and building characteristics contained in the USEPA Johnson and Ettinger model were used in this evaluation. These values are presented in Table 2. Table 3 presents the indoor air concentrations predicted by the Johnson and Ettinger model for each of the COPCs.

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 modeling input parameter that considers soil moisture is the water-filled porosity, which is determined by the soil moisture content and the dry bulk density. Although there is adequate soil moisture content from the site itself, 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 bulk density from the Borrow Area data of 1.83 g/cm^3 and an average soil 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 = 0.90) are used in the modeling effort for the property.

3.3 Risk Assessment Methodology

The method used in the screening-level indoor air health risk assessment consists of several steps. The first step is the calculation of exposure point concentrations representative of the particular 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 next 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 DBSA 2007) provides a full discussion on the risk assessment methodology for the project, and used in this screening-level indoor air health risk assessment.

Table 2 presents each of the exposure parameters used in the screening-level indoor air health risk assessment. Toxicity values, when available, are published by the USEPA in the on-line Integrated Risk Information System (IRIS; USEPA 2008) 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 2007) was used.

3.4 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 in order 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 health risk assessment 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 health risk assessment is provided below.

The screening-level indoor air health risk assessment for the property was based on the sampling results obtained from aan 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. However, the number of sampling locations are spread across the propertyand events is large and widespread, and sampling was performed using approved procedures; therefore, the sampling and analysis data is sufficient to characterize the impacts and the associated potential risks.

The amount of COPCs the body absorbs may be different from the amount of a COPC contacted. In this screening-level indoor air health risk assessment, absorption of inhaled COPCs is conservatively assumed to be 100 percent. Actual chemical and site specific values are likely less than this default value.

The Johnson and Ettinger model default building characteristics assume a residential building type. However, the planned use of the property is for redevelopment into commercial use. Commercial building parameters typically result in indoor air concentrations lower than those for a residential building. For example, the recommended building air exchange rate from the California Department of Toxic Substances (DTSC; 2005) for a commercial building is 1.0 per hour versus the model default for a residential building of 0.25 per hour. This parameter alone could result in a one-fourth reduction in the indoor air concentration.

Toxicity criteria have not been established for many of the chemicals detected at the property. These chemicals were not quantitative evaluated in the screening-level indoor air health risk assessment. Thus, the risks presented in this assessment could be underestimated as a result.

The selection of exposure pathways is a process, often based on best professional judgement, which attempts to identify the most probable potentially harmful exposure scenarios. In a risk assessment it is possible that risks are not calculated for all of the exposure pathways that may occur, possibly causing some underestimation of risk. In this assessment, risks were estimated for one receptor; future on-site indoor commercial workers. Risks for the most likely route of exposure to future on-site indoor commercial workers were estimated. Specifically, risks to future on-site indoor commercial workers were estimated for inhalation of indoor air. Although it is possible that other exposure routes could exist, these exposures are expected to be lower than the risks associated with the pathway considered.

Uncertainties from different sources are compounded in the screening-level indoor air health risk assessment. 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 health risk assessment are likely to overestimate rather than underestimate potential risks.

3.5 Screening-Level Indoor Air Health Risk Assessment Results

This screening-level indoor air health risk assessment has evaluated potential risks to human health associated with chemicals detected in soil gas at the Tronox Parcels A and B property. The calculation of chemical theoretical upper-bound ILCRs and non-cancer health effects are presented in Table 4. All calculation spreadsheets for this screening-level indoor air health risk assessment are included in Attachment BA.

The total cumulative non-cancer HI for future on-site indoor commercial workers at the property is 0.01, which is below the target HI of 1.0. Therefore, because the total cumulative HI is below 1.0, the potential for adverse health effects is considered unlikely.

The theoretical upper-bound ILCR for future on-site indoor commercial workers at the property is 4 2 $\times 10^{-6}$. The risks are primarily driven by chloroform, which contributes 95 percent of the theoretical upper-bound ILCR. Although the ILCR is above the risk goal of 1×10^{-6}, it is within the acceptable risk range from 10^{-6} to 10^{-4}. Therefore, these results indicate that future receptor exposures at the property should not result in unacceptable carcinogenic risks.

4.0 Summary

Based on the results of the 2008 soil gas investigation, this data review, and the screening-level indoor air health risk assessment, concentration levels of chemicals in soil gas at the Tronox Parcels A and B property are not at levels of concern for human health risk for an indoor commercial scenario. In addition, the screening-level health risk assessment is 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). Based on the results of the 2007 investigation and the 2008 screening-level health risk assessment, concentration levels of chemicals at the Tronox Parcels A and B property are not at levels of concern for human health risk for an industrial scenario. BEC concluded, and NDEP concurred, that an NFAD for the property was warranted.

A quantitative summing of the risks associated with the 2008 screening-level health risk assessment and this current screening-level indoor air health risk assessment is considered inappropriate given their differing methodologies; however, qualitatively the risks for both risk assessments combined would be less than an HI of 1.0 for non-carcinogens and the theoretical upper-bound ILCR would be within the acceptable risk range for carcinogens. Thereforesummary, BEC concludes that an NFAD for the property is further supported by these results.

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Attachments: Figure 1 – Tronox Parcels A/B Phase B Soil Gas Sample Locations
Table 1 – Chemicals of Potential Concern and Representative Exposure Concentrations in Soil Gas
Table 2 – Johnson and Ettinger Model Input Parameters
Table 3 – Model Estimated Indoor Air Concentrations
Table 4 –Screening-Level Indoor Air Health Risk Assessment Results
Attachment A – Tronox/BEC Response to Comments and Redline Version of the Text
Attachment B – Screening-Level Indoor Air Health Risk Assessment Calculation Spreadsheets (on CD)

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all applicable federal, state and local statutes, regulations and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

March 30, 2010~~November 3, 2008~~

Dr. Ranajit Sahu, C.E.M. (No. EM-1699, Exp. 10/07/2011~~2009~~)
Date
BRC Project Manager

ATTACHMENT B

SCREENING-LEVEL INDOOR AIR HEALTH RISK ASSESSMENT CALCULATION SPREADSHEETS (ON CD)