Revised Indoor Air Quality Investigation Work Plan
Tronox LLC Facility
Henderson, Nevada

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Responsible Certified Environmental Manager (CEM) for this project

I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

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.

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Susan M. Crowley, CEM 1428 Exp.:03/08/11
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ACRONYM LIST

Acronym	Definition
BCL	Basic Comparison Level
DVSR	Data Validation Summary Report
ELAP	Environmental Laboratory Approval Program
ER	Exchange Rate
GC/MS	Gas Chromatograph/Mass Spectrometer
HRA	Health Risk Assessment
HVAC	Heating, Ventilation, and Air Conditioning
J&E	Johnson and Ettinger
NDEP	Nevada Division of Environmental Protection
NIOSH	National Institute of Occupational Safety and Health
ppb	Parts Per Billion
ppm	Parts Per Million
QA/QC	Quality Assurance/Quality Control
Q_{soil}	vapor flow rate
SIM	Selected Ion Monitoring
TCE	Trichloroethene
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compound

1.0 INTRODUCTION

A soil gas survey was conducted under the oversight of Nevada Division of Environmental Protection (NDEP) as part of the Phase B Source Area Investigation at the Henderson facility (the Site). Soil gas samples were collected from May 7 through May 29, 2008. The Soil Gas Data Validation Summary Report (DVSR) was submitted to NDEP on October 13, 2008. In general, chloroform, trichloroethene (TCE), and carbon tetrachloride were detected at elevated concentrations in soil gas samples obtained at the Site. Some of the elevated soil gas concentrations are associated with off-site groundwater sources. Tronox LLC (Tronox) proposes to perform an indoor air quality investigation to evaluate the vapor intrusion pathway and for comparison with indoor air vapor intrusion modeling results for select chemicals of interest.

As outlined in the Health Risk Assessment (HRA) Work Plan, the Johnson and Ettinger model, hereafter referred to as the J&E model (USEPA, 2004; Johnson and Ettinger, 1991), will be used with the collected soil gas data to estimate potential exposure point concentrations for organic chemicals in order to evaluate the indoor air vapor intrusion exposure pathway. As part of an initial evaluation, Site-specific J&E input parameters and resultant site-specific soil gas screening values were submitted to NDEP on January 29 (Northgate, 2010a) and February 10, 2010 (Northgate, 2010b). A range of soil gas screening values were calculated based on the most conservative and least conservative proposed input parameters for indoor air exchange rate (ER) and average vapor flow rate into building (Q_{soil}), referred to as the lower screening limit and upper screening limit, respectively.

Based on this initial evaluation, measured soil gas concentrations of chloroform, TCE, and carbon tetrachloride exceed their respective lower soil gas screening limits. Only chloroform exceeds its respective upper soil gas screening limit.

As soil gas vapor intrusion modeling methodologies often incorporate conservative assumptions that may overestimate actual indoor air concentrations, the purpose of this work plan is to outline the type of indoor air testing to be conducted to supplement the indoor air vapor intrusion modeling evaluation[1]. The air sampling data will be included as part of the uncertainty

[1] In August 2008, Tronox conducted indoor air testing for chloroform in the engineering building and Unit 4 building, as these buildings were near some of the higher chloroform soil gas concentrations. Fourteen air samples were collected and analyzed for chloroform (seven in each of the two buildings). Airborne chloroform samples were collected using SKC diffusion badges over a 7 to 8 hour time period and analyzed using National Institute of Occupational Safety and Health (NIOSH) method number 1003. Airborne chloroform was not detected at a detection limit of 2 parts per million (ppm; 2,000 parts per billion [ppb]). Although this detection limit is significantly below the 8-hour occupational recommended threshold limit value of 10 ppm, it is above the NDEP ambient air Basic Comparison Level (BCL) of 0.02 ppb (0.1 ug/m^3)

evaluation in the HRA to provide context with regards to the indoor air exposure pathway and assessment of potential worker health risks.

This work plan addresses the following items:

- Building evaluation;
- Supplemental indoor air sampling strategy, including types and number of samples to be collected, locations of samples, and sampling methods; and
- Interpretation of sampling data and recommendations.

2.0 SAMPLING PLAN

The objective of this indoor air quality investigation is to collect data to evaluate the indoor air vapor intrusion exposure pathway. Findings will be used to supplement the indoor air modeling efforts conducted as part of the HRA. The following sections describe the sampling approach and locations.

2.1 Building Evaluation

As an initial step to the air sampling plan, a Site visit will be conducted to obtain further information about those buildings located near the elevated soil gas concentrations and to finalize the indoor air sampling procedures. Information to be gathered or confirmed will include location of the buildings, type of building construction, type of foundation, type of building ventilation (e.g., heating, ventilation, and air conditioning [HVAC], open building, etc.), and building occupancy use (including possible use of products containing volatile organic compounds [VOCs] by building occupants). Based on the results of the Site visit, the number of buildings to be included in the air sampling program, as well as the rationale for building inclusion, will be identified. A Site Figure will be prepared showing all buildings to be included in the air sampling plan. If buildings are to be demolished prior to remediation and as part of the Site closure, they will be not be included in the air sampling program. A building survey form is included as Appendix A.

2.2 Sampling Strategy

Indoor air samples will be collected to characterize concentrations of VOCs within buildings and outdoors at the Site in order to evaluate the significance of the soil gas to indoor air exposure pathway and to assess the health significance of indoor air concentrations of these compounds. Outdoor air samples will be collected at building air intake locations (secondary measurements on air going into the buildings), or at upwind locations onsite (local outdoor air concentrations). Based on groundwater and soil gas data collected at the Site, chloroform, TCE, and carbon tetrachloride are the primary chemicals of interest and will be used to evaluate the vapor intrusion pathway and for comparison with J&E modeling results.

Several factors may influence the concentrations of chemicals measured in indoor air, including building-specific operations and ventilation systems as well as environmental factors such as ambient sources and vehicle traffic. Indoor air concentrations are likely to fluctuate, therefore, the indoor air sampling approach will involve multiple sampling events to aid in the interpretation of the results. Sampling will be conducted over a minimum of two seasons (e.g., late spring and early fall) to understand different meteorological conditions and potential differences in building operations. Depending on the results of the individual building surveys, additional rounds of sampling may be conducted to capture potential indoor air concentration variability.

2.3 Sampling Methodology

Air samples will be collected using passivated steel Summa canisters to be certified for selected ion monitoring (SIM) analysis and provided by the Environmental Laboratory Approval Program (ELAP) - certified analytical laboratory. Indoor air samples will be collected over a 6- to 8-hour work day. The samples will be collected using a sampling train of components that regulate the rate and duration of sampling into the Summa canisters. For indoor air sampling, the flow controllers will be set to collect approximately 5 liters of air over an 8-hour sampling interval. For outdoor air sampling, the flow controllers will be set up to collect approximately 5 liters of air over an approximate 9- to 10-hour sampling interval. As ambient air is likely to enter a building before indoor air sampling begins, outdoor sampling will begin 1 to 2 hours prior to indoor air sampling and will continue to be collected until at least 30 minutes prior to the end of the indoor air sampling period. Initial and final canister pressures will be recorded. Sampling will be conducted during regular work hours to provide the best estimate of potential exposure concentrations. Sampling and field documentation procedures are provided in Appendix B.

Samples will be analyzed using the TO-15 gas chromatograph/mass spectrometry (GC/MS) SIM method by an ELAP-certified laboratory. Laboratories will be required to meet a reporting limit in the range of 0.1 to 0.20 $\mu g/m^3$ for the chemicals of interest.

On the day of sampling, the building will be inspected by an industrial hygienist to identify and minimize conditions that may interfere with the testing and to ensure consistency with the information gathered during the initial building evaluation. In addition, the following information will be documented:

- Use of chemicals in building (e.g., for building maintenance or in storage);
- Use of HVAC system;
- Floor sketches that document building layout, location of samples, chemical storage, HVAC system supply and return registers, and other pertinent information;
- Outdoor plot sketch noting location of outside and roof samples;
- Weather conditions, including indoor and outdoor temperature and humidity; and
- Other pertinent observations (e.g., spills, odors).

2.4 Sample Locations

2.4.1 Indoor Air Samples

After completion of the building evaluation, the number and location of air samples will be finalized. It is anticipated that two to eight indoor air samples will be collected in each building selected for inclusion in the indoor air sampling program depending on building size, location relative to soil gas concentrations and other pertinent building features. At least one sample will be collected in a worker-occupied space. All indoor air samples will be collected at a height approximately 3 to 5 feet above the floor, to represent a height at which occupants normally are seated. In addition to air sampling, barometric pressure readings will be taken in each building to determine whether it is under positive or negative pressure.

2.4.2 Building Air System Samples

A HVAC roof inlet sample will be collected when feasible to characterize chemical concentrations in the air coming into each building from outdoors. These data, in conjunction with information on air flow rates, fresh air make-up, and recirculated air within the building, will provide a characterization of building air (i.e., characterization of concentrations coming into the building). Fresh air make-up will be measured by accessing the outdoor air intakes for each of the air handling units. Air velocity will be measured and the dimensions of each intake will be determined to calculate the outdoor air ventilation being drawn into the building. This methodology can be used when all windows are closed and the only source of outdoor air is via the intakes on the HVAC systems. Recirculated air within the building can be estimated based on the specifications of each air handling unit, or it may be measured based on air velocity traverses of supply and return air ducts.

2.4.3 Site Outdoor Ambient Air Samples

Outdoor air samples will be collected to characterize ambient concentrations and evaluate, in part, contributions from other local sources. One outdoor sample will be collected upwind of the Site. Specific sampling locations will be determined based on wind direction at the Site on the day of sampling. Sample locations will be selected that are away from wind obstructions (e.g., tress or bushes), and the samples will be collected at 3 to 5 feet above the ground to represent the breathing zone.

2.5 Quality Assurance and Quality Control (QA/QC) Samples

All QA/QC samples will be shipped to the same analytical laboratory and analyzed using the same preparatory and analytical methods used for all the other samples. One field blank will be obtained. The field blank results are intended to verify sample integrity during field sample collection. A laboratory blank sample will be provided and analyzed by the laboratory operating the instruments. Blank levels will be used to establish the system baseline. A blank will be performed for the GC/MS SIM operation.

3.0 DATA INTERPRETATION

Data will be reviewed, and their representativeness and reliability will be verified to ensure that the analytical data package and all associated QA/QC information are complete. An assessment of the usability of the data will be provided.

Detection of chemicals in indoor air samples does not necessarily indicate that soil vapor intrusion is occurring or that action should be taken to address exposure. Indoor air results will first be compared to the HVAC roof inlet concentrations, as well as to national and Site-specific background concentrations. Several studies have been conducted to determine indoor and outdoor air background levels of various compounds in a variety of settings. The statistical variability within background sampling will be considered in this evaluation.

The indoor air concentrations will also be evaluated in terms of the results of the J&E vapor intrusion modeling results and will include a discussion of the following items:

- Indoor environment and building characteristics;
- Potential outdoor sources; and
- Potential for migration from the subsurface including comparison of VOCs ratios detected in indoor air to VOCs ratios detected in soil gas.

A discussion of the measured air concentrations compared to the J&E modeled indoor air concentrations will be presented. This information will also be included as part of the uncertainty evaluation in the HRA to provide context with regard to the indoor air exposure pathway. Additionally, the measured air concentrations will be discussed in terms of human health risks.

4.0 REFERENCES

Johnson, P.C. and R.A. Ettinger, 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. Environmental Science and Technology, 25:1445-1452.

Northgate, 2010a. Memorandum re: Soil Gas Approach from Deni Chambers, Northgate, and Greg Brorby, Exponent, to Brian Rakvica, NDEP. January 29.

Northgate, 2010b. Memorandum re: Site-Specific Input Parameters for the Johnson & Ettinger Model from Deni Chambers, Northgate, and Greg Brorby, Exponent, to Brian Rakvica, NDEP. February 10.

USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. Prepared by Environmental Quality Management, Inc. for the U.S. Environmental Protection Agency (Office of Emergency and Remedial Response, Washington, D.C.). February 22.

APPENDIX A - BUILDING SURVEY FORM

This form must be completed for each building involved in an indoor air investigation.

Preparer's name:		Date prepared:		
Preparer's affiliation:		Telephone number:		
A. Type of Building Construction				
1. Building type (circle appropriate responses):				
Industrial	Office		Warehouse	Other:
2. Building age:		Number of stories:		
3. Building area (square feet):		Is the building insulated? Y / N		
4. How sealed is the building?				
5. General description of building construction materials:				
B. Foundation Characteristics (circle all that apply)				
1. Basement	Slab on grade		Other:	
2. Basement floor description: concrete, dirt, wood, other:				
a. The basement is: wet, damp, dry				
b. The basement is: finished, unfinished				
c. Is the basement sealed? (provide a description)				

3.	Concrete floor description: unsealed, painted, covered with:		
4.	Foundation walls: poured concrete, block, stone, wood, other:		
5.	Identify all potential soil gas entry points and their size (e.g., cracks, voids, pipes, utility ports, sumps, drain holes, etc.). Include these points on the building diagram.		
C.	**Heating, Ventilation, and Air Conditioning** (circle all that apply)		
1.	The type of heating system(s):		
	Hot Air Circulation	Heat Pump	Hot Water Radiation
	Steam Radiation	Electric Baseboard	Other (specify):
2.	Location of heating system:		
3.	Is there air-conditioning? Y / N	Central air or window units?	
	Specify the location:		
4.	Are there air distribution ducts present? Y / N		
5.	Is there a fan? Y / N		
a.	What is the rated size of the fan?		
6.	Temperature settings inside during sampling. Note day and night temperatures. Note times if system cycles during non-occupied hours during the day.		
	a. Daytime temperature(s):	b. Nighttime temperature(s):	
7.	Estimate the average time doors and windows are open to allow fresh outside air into the building. Note rooms that frequently have open windows or doors.		

8.	Results of ventilation measurements obtained during building survey:
D.	**Potential Indoor Sources of Pollution** An inventory of all products used or stored should be performed. Any products that contain volatile organic compounds or chemicals similar to the target compounds should be listed.

E. Plan View Sketch

Sketch each floor and if applicable, indicate proposed air sampling locations, possible indoor air pollution sources, and preferential pathways.

APPENDIX B – SAMPLING PROTOCOL

Each pre-evacuated canister received from the laboratory should come with a brass plug, vacuum gauge, flow controller, and particulate filter. The brass plug ensures that there is no loss of vacuum due to a valve accidentally being opened during shipment. The plug also prevents dust from contacting the valve. A vacuum gauge is used to measure the initial and final vacuum of the canister and to monitor the canister when collecting an integrated sample. A flow controller (critical orifice) is used when taking an integrated sample over time. Prior to shipment, the laboratory confirms the flow rates for each orifice. It is imperative that orifices be certified "clean" prior to use; therefore, orifices should not be re-used in the field. When canisters are requested from the laboratory, the sampling duration will be specific so that the laboratory can pre-set the flow controller rates

Sampling Procedures

1. Unpack canisters from shipping container. Verify that all equipment components are present and the canister valve is closed.
2. Mark each canister with a discreet sample number. Indicate the sample number and flow controller serial numbers on the chain-of-custody form.
3. Remove the brass plug from the canister valve, and attach the vacuum gauge tightly. If you are using a gauge with a "Tee" fitting, cap the side arm of the "Tee" with the brass plug.
4. Open and close the canister valve. The gauge will register the level of vacuum present. Record this value on the chain-of-custody form for the canister. The initial vacuum of the canister should be >25-in Hg (inches mercury). If the canister vacuum is less than 25-in Hg, do not use - arrange for a replacement canister.
5. Verify that the canister valve is closed. Remove the vacuum gauge and replace the brass plug on the canister valve.
6. Remove particulate filter and pre-calibrated flow controller from packaging. Place particulate filter on flow controller inlet.
7. Remove brass plug from canister valve, and attach flow controller (with particulate filter) to canister valve.

8. Place canister at sample location. In general, the material of the canister is heat resistant. However, the canisters should be kept out of direct sunlight during sampling.
9. Open valve and record sampling time.
10. Check canister integrity during the sampling interval. For 8-hour samples, the flow controller often includes a pressure gauge as part of the hardware. This vacuum gauge should not be used in place of the vacuum gauge used to record pre- and post-vacuum readings, but can provide a general indication of pressure. For example, 4 hours into an 8-hour sampling event, the canister should contain 2.5 L, and the pressure should be approximately 15-in Hg. Less than 20-in Hg indicates that the canister is filling too slowly; more than 10-in Hg indicates the canister is filling too quickly, and corrective action may be necessary, including adjusting the flow or resampling.
11. At the end of the sampling period, close the valve and record the time, temperature, and final canister pressure.
12. Remove flow controller (with particulate filter) and attach vacuum gauge. Open and close the canister valve. The gauge will register the level of vacuum present. Record this value on the chain-of-custody form for the canister. The final pressure of a 6 L canister should range between 4 and 8-in Hg. If the vacuum is greater than 8-in Hg, the sample was collected at a lower flow rate. The laboratory will need to apply a greater dilution factor to the sample, resulting in elevated limits of detection. If the final vacuum is less than 4-in Hg, either the flow rate was too high or the pressure difference across the flow controller diaphragm was too small. Either condition means that the sample is skewed toward the initial sampling interval. This is a non-linear sample but may still be considered valid. If the final pressure is near ambient (near 1-in Hg), it must be considered an invalid integrated sample.
13. Remove vacuum gauge. Place brass plug on canister valve and tighten. It is not necessary to over-tighten the fittings. Finger tight plus 1/16 turn is adequate. However, it is essential that all the connections between the canister and the flow controller be tight and immobile by hand. A leak in any one of these connections means that some air will be pulled in through the leak and not through the flow controller. A final pressure near ambient is one indication that there may have been a leak.

14. Repackage the sampling hardware. Complete the chain-of-custody form and ensure that air samples are properly labeled. Indicate TO-15 SIM as the analytical method to be used.
15. Return canisters to laboratory with chain-of-custody form. For air sample containers, there are no special storage or handling requirements. The canisters will be shipped to the laboratory in the original box.

Field Documentation

Sampling information will be recorded on a chain-of-custody form and in a field log. All documents will be completed in the field at the time of sample collection. Samples are also labeled in the field at the time of collection. Samples will be labeled with the following information, at a minimum:

- Project number;
- Sample location and identification number;
- Date and time of sampling;
- Sampler's name; and
- Required analysis.

Chain-of-custody forms generally contain the following information:

- Sampler's name and signature;
- Sample identification number;
- Date and time of sampling;
- Sample matrix (air) and number of containers included per sample (one);
- Required analysis (TO-15 SIM) and turnaround time (standard 10-day);
- Laboratory name and instructions to technicians;
- Date and time of sample receipt; and
- Transfer signatures.

All entries for sample collection will be recorded in field logs that will contain the following information:

- Building, location, and date;
- Personnel in attendance;

- General weather conditions and field observations;
- Sampling and field analysis performed;
- Problem encountered and corrective measures taken;
- Identification of any quality control samples; and
- Anything that may affect the quality of the samples.