Risk Assessment of Ambient Air Collected Near the Chrin Brothers, Inc. Sanitary Landfill

Report

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EXECUTIVE SUMMARY

In January and February, 2009, EarthRes Group collected ambient air samples at seven different locations near the Chrin Brothers, Inc., Sanitary Landfill on seven different dates[1]. Each of these samples was analyzed for over 60 Volatile Organic Chemicals commonly recognized as being potentially hazardous. Based on these analyses, a total of nine chemicals were identified at one or more of the sampling locations. Four of the nine identified chemicals were detected in only one of the 47 samples, and no chemical was detected in more than 25 % of the samples. The sampling locations were scientifically selected to represent both up-wind and down-wind of the Chrin Brothers Landfill. Three of the sampling locations were located west of the landfill area, one was located north of the landfill, one was within the area of the landfill and two were east of the landfill close to the adjacent, high-density residential area.

The chemicals detected are all common chemicals that are present in ambient air from many potential sources – both naturally-occurring and derived from human activities. These chemicals are routinely found across similar metropolitan areas in the U.S. in ambient air sampling. In order to determine if there were any scientifically-calculated, unacceptable risk to nearby residents due to the presence of these chemicals, a "risk assessment" was conducted using widely recognized procedures.

The risk assessment estimated both the potential carcinogenic (i.e., cancer) risk and non-carcinogenic health effects. Only two of the total number of chemicals detected in the sampling by EarthRes Group are even suggested to be potential carcinogens (Ethylbenzene and Tetrahydrofuran), and both are based on studies in animals. Neither US EPA nor the National Toxicology Program currently lists either of these chemicals as potential carcinogens in humans. Nevertheless, in order to conduct a conservative analysis of the potential carcinogen risk, and in the interest of transparency, they were both evaluated at the concentration detected in the single sample and treated as being carcinogenic.

All of the nine chemicals, except for the two common alcohols (ethyl alcohol and isopropyl alcohol), were evaluated for the possibility of producing non-carcinogenic health effects, based on the maximum concentration detected in the 47 sampling events.

This risk assessment applied several conservative assumptions to assure that the potential human health effects were not underestimated. These assumptions included: 1) using the

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[1] Samples were collected from one of the sampling points on five, not seven, occasions.

maximum concentration of chemical regardless of the location detected; 2) a continuous 30-year exposure for 24 hours a day; 3) the toxicity value used for the assessment; and 4) no dispersion of the air samples was assumed.

The results of the risk assessment indicated the following:

- **Non-carcinogenic hazard**
    - There is no expectation of adverse health effects for any of the chemicals alone or in combination.

- **Carcinogenic risk**
    - The two sampling locations closest to the adjacent residential area did not have any detections of any possible carcinogenic chemicals, and there is no elevated cancer risk downwind of the landfill.
    - One sampling location, on Landfill Property, had a minute level of risk present, based on the detection of the two possible carcinogens in one of seven samples for the location. This level of risk is below the level determined by the PA DEP to be acceptable for the total calculated carcinogenic risk of 7 excess cancers per one million exposed individuals.
    - The remaining five sampling locations had no detectable levels of any chemicals identified as possible carcinogens

The bottom-line conclusions from this risk analysis: there is no evidence of any unacceptable risk of adverse human health effects due to the chemicals identified in the EarthRes Group sampling conducted in January and February 2009.

- **Toxicity Assessment**: What toxicity factors (i.e., Cancer Slope Factors, or Reference Doses) have been developed for the various COPCs;
- **Risk Characterization:** involves multiplying the Cancer Slope Factor by the Lifetime Average Daily Dose of each COPC, and summing the individual cancer risks, or Dividing the Average Daily Dose by the Reference Dose to determine if adverse health effects are possible.

Supporting information for each of these issues is provided herein.

HAZARD IDENTIFICATION

During this step, the identification of COPCs is performed. COPCs for this activity included all VOCs that were detected during the ambient air sampling. Many were identified only once, but were included in the analysis. The EarthRes Group Report, March 2009, provided a summary of the analytical results associated with air sampling conducted between January 9, 2009 and February 15, 2009. The identified substances found in these 47 sampling events are presented below. The maximum concentration and number of detections also are presented.

Substance	**Maximum Concentration** $\mu g/M^3$	**# Detects/ # Samples**
Acetone	16	11/47
2-Butanone (Methyl Ethyl Ketone)	8.4	9/47
Carbon Disulfide	10	3/47
Ethanol	12	3/47
Ethylbenzene	3.1	1/47
2-Propanol (Isopropyl alcohol)	7.3	1/47
Tetrahydrofuran	2.8	1/47
Toluene	7.6	5/47
m,p- Xylene	4.8	1/47

There were a total of 62 VOCs analyzed for by the laboratory, but only these nine were detected above the laboratory detection limit in any of the 47 samples collected.

REVIEW OF TOXICOLOGY OF IDENTIFIED CHEMICAL SUBSTANCES

The following is a discussion of the substances identified above that may have a potential for producing human health effects. Throughout this document scientific notation is used to refer to both the toxicology values and the Risk/Hazard results. Scientific notation is a way of writing numbers that are too large or too small to be conveniently written in standard decimal notation. For example, 3.4E-04 is the same as 3.4 X 10^{-4}, or 0.00034; and 4.8E+5 is the same as 4.8 X 10^{+5}, or 480,000. Each of the identified substances is discussed below.

Acetone

Acetone is a chemical that is both naturally occurring and produced by industries. Low levels of acetone are produced in the body from the breakdown of fat. Acetone is a liquid that evaporates readily into the air. Several consumer products contain acetone, including: nail polish removers, particle board, paint removers, certain paste waxes and cleansers. There is no evidence that Acetone can produce cancer in either animals or humans.

The current United States Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL)[2] for Acetone is 1,000 ppm or 2,400 mg/M^3 (i.e., 2,400,000 µg/M^3). The Agency for Toxic Substances and Disease Registry (ATSDR) has developed a chronic Minimal Risk Level (MRL) (defined as a level that individuals can be exposed to chronically, and not experience adverse Health effects) at 13 ppm, or 30.9 mg/M^3 (i.e., 30,900 µg/M^3). ATSDR indicates that outdoor ambient air typically ranges between 1 and 6.9 ppb (2.3 to 16.4 µg/M^3). Acetone was detected in 11 of the 47 samples collected by EarthRes Group. The maximum value was collected at station # 3 was 16 µg/M^3, well less than the OSHA PEL of 30,900 µg/M^3 and well within the range that ASTDR indicates is a normal background level.

2-Butanone (Methyl Ethyl Ketone)

2-Butanone is a liquid used in paints, glues and other finishes, because it rapidly evaporates. It is also a natural product made by some trees and found in some fruits and vegetables, and in car exhaust.

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[2] The **Permissible Exposure Limit (PEL or OSHA PEL)** is a legal limit that regulates employee exposures of employees to a chemical substance. PEL's are typically expressed as a time-weighted average, not instantaneous maximums.

Serious health effects in animals have only been seen with very high concentrations of 2-butanone. 2-Butanone has been found in outdoor air at concentrations of zero up to 14 ppb (i.e. up to 41 μg/M^3). There is no evidence that 2-Butanone can produce cancer in either animals or humans. The current OSHA PEL for 2-Butane is 200 ppm or 590 mg/M^3 (i.e., 590,000 μg/M^3). The IRIS Database lists an RfC_i for 2-Butanone of 5 mg/M^3 (i.e., 5,000 μg/M^3), indicating that continuous exposure to this level would not be expected to result in adverse health effects. 2-Butanone was detected a total of nine times out of the 47 samples with the Maximum value of 8.4 μg/M^3 found at station # 3, well less than the OSHA PEL of 590,000 μg/M^3 and well within the range that ASTDR indicates is a normal background level.

Carbon Disulfide

Carbon Disulfide is widely used as an industrial solvent and as an insecticide. Carbon disulfide evaporates readily in the atmosphere.

The OSHA PEL for carbon disulfide is 20 PPM (61,000 μg/M^3). The ATSDR has developed a chronic MRL of 0.3 ppm or 933 μg/M^3. This chemical was identified 3 times in the air sampling and two of the locations were considered up-wind. The IRIS Database lists an RfC_i for Carbone Disulfide of 0.7 mg/M^3 (i.e. 700 μg/M^3), indicating that continuous exposure to this level would not be expected to result in adverse health effects. Carbon Disulfide was only detected three times out of the 47 samples, with a maximum value of 10 μg/M^3 found at station # 1 (an up-wind location).

Ethanol

Ethanol or Ethyl alcohol is the alcohol obtained from fermentation and found in alcoholic beverages. It is also being widely used as an alternative fuel. Ethanol obviously can produce intoxication when consumed, and is regulated from a safety standpoint. Ethanol has been recognized as a potential carcinogen when consumed in large quantities over a lengthy period of time, resulting primarily in tumors of the mouth, esophagus, stomach, liver and kidney. However, Ethanol is not evaluated as a carcinogen by the regulatory agencies, since the doses obtained by alcoholic beverage consumption far exceed any potential environmental exposure. For example, a typical alcoholic drink contains about 14 grams of ethyl alcohol or 0.20 gm/kg (body weight). The current OSHA PEL for Ethanol is 1,000 ppm or 1,900,000 μg/M^3. Ethanol was not evaluated in this assessment, since no toxicology values are available and the levels identified were essentially similar to the outdoor air samples. Even at the one higher level of 12 μg/M^3, an adult resident would only receive a dose of 240 μg in a day, or 2.4 μg/kg. This is approximately 80,000 times less than an individual would receive from one alcoholic drink. Ethanol was detected in three samples out of the total of 47, with the maximum value of 12 μg/M^3 found at Station # 3, well below the OSHA PEL of 1,900,000 μg/M^3.

Ethyl Benzene

Ethyl Benzene is found in fuels and solvents, and is one of the BTEX compounds associated with gasoline. According to the ATSDR indoor air concentrations have been found to range from 1 to 13 ppb. In recent outdoor air samples collected along a highway in North Carolina, the levels of Ethylbenzene ranged from 44 to 70 μg/M^3. Ethyl benzene is also found in pesticides, glues varnishes and cigarette smoke.

The OSHA PEL for Ethyl Benzene is 100 ppm (435,000 μg/M^3). The ATSDR has developed a chronic inhalation MRL of 0.3 ppm or 1.3 mg/M^3 (i.e., 1,300 μg/M^3). The IRIS Database lists an RfC_i for Ethyl Benzene of 1 mg/M^3 (i.e., 1,000 μg/M^3), indicating that continuous exposure to this level would not be expected to result in adverse health effects. Ethylbenzene is not listed as a carcinogen in the PADEP Land Recycling Database or in the IRIS database; however, the ORNL database does list Ethylbenzene as a potential carcinogen and lists a cancer slope factor. In this assessment Ethylbenzene was evaluated as a carcinogen, and discussed in the conclusions. Ethylbenzene was only detected in one of the 47 samples at Station # 5, with a value of 3.1 μg/M^3.

2-Propanol

2-Propanol is also known as isopropyl alcohol or rubbing alcohol, and is a common solvent used by the public. Isopropyl alcohol is similar to ethyl alcohol, but is about twice as toxic in terms of producing intoxication. The OSHA PEL for 2-Propanol is 400 ppm (980,000 μg/M^3). 2-Propanol was not evaluated in this assessment, since no toxicology values are available and it was only detected once at a low level. 2-Propanol was detected in one of the 47 samples at Station # 5, with a value of 7.3 μg/M^3.

Tetrahydrofuran

Tetrahydrofuran is a liquid used as a solvent and chemical starting material. It is used in preparation of inks, adhesives, lacquers and other coatings. The OSHA PEL for Tetrahydrofuran is 200 ppm (590,000 μg/M^3). According to the PADEP Land Recycling website, Tetrahydrofuran is listed as a potential carcinogen with a CSFi of 6.8E-03 mg/kg/day. This value apparently comes from a NCEA Provisional value, but is not included in the IRIS database or the ORNL Database. In this Risk Assessment it was evaluated as a carcinogen, and is discussed in the conclusions. Tetrahydrofuran was only detected in one of the 47 samples at Station # 5, with a value of 2.8 μg/M^3.

Toluene

Toluene is one of the BTEX compounds and occurs naturally in crude oil. It is used in many products, including: paints, paint thinners, fingernail polish, lacquers, adhesives and rubber. Toluene has not been classified to be a carcinogen by any regulatory agency.

The OSHA PEL for Toluene is 200 ppm (754,000 $\mu g/M^3$). U. S. EPA has developed an Inhalation RfCi for Toluene of 5 mg/M^3 (i.e., 5,000 $\mu g/M^3$), which means if long-term exposure exceeds 5 mg/M^3, that there is the potential for adverse health effects. The ATSDR has determined a chronic MRL to be 0.08 ppm or 0.30 mg/M^3 (i.e. 300 $\mu g/M^3$). The IRIS Database lists an RfC_i for Toluene of 5 mg/M^3 (i.e., 5,000 $\mu g/M^3$) , indicating that continuous exposure to this level would not be expected to result in adverse health effects. Toluene was detected in a total of five of the 47 samples, with the maximum value of 7.6 $\mu g/M^3$ detected at Station # 5.

M, P and O –Xylenes

There are three different chemicals with very similar properties identified as xylenes, and are recognized as components of the BTEX compounds associated with gasoline. For this discussion o, m, and p forms are discussed together. These xylenes are found in a variety of products including: gasoline, paint varnishes, and cigarette smoke. According to the ATSDR normal outdoor air levels of total xylenes typically range from 1 to 30 ppb (4.3 to 130 $\mu g/M^3$).

The OSHA PEL for Xylenes is 100 ppm (435,000 $\mu g/M^3$). The ATSDR has determined a chronic MRL to be 0.05 ppm or 0.21 mg/M^3 (i.e., 210 $\mu g/M^3$). The IRIS Database lists an RfC_i for Xylenes of 0.7 mg/M^3 (i.e., 700 $\mu g/M^3$), indicating that continuous exposure to this level would not be expected to result in adverse health effects. M, P Xylene was detected in one of the 47 samples at Station # 5, with a value of 4.8 $\mu g/M^3$.

EXPOSURE ASSESSMENT

The exposure assessment evaluates the likelihood, magnitude and frequency of exposure to the COPCs, and identifies pathways and routes by which these specific human receptors may come into contact with these constituents. The specific steps involved in the exposure assessment include the following:

Characterization of Exposure Setting

- Description of the physical setting

- Identification of potential exposure

Identification of Exposure Pathway

- Identification of media of concern
- Identification of actual and potential exposure routes

Development of Exposure Scenarios

- Selection of exposure scenarios
- Establishment of exposure parameters

Quantification of Exposure

- Estimation of exposure point concentrations
- Estimation of exposure doses

As detailed in the following subsections, the primary purpose of the EarthRes Group Study and this risk assessment was to evaluate the potential human health risk associated with airborne VOCs that might be associated with the Chrin Brothers Landfill. Accordingly, the only potential exposure pathway is through inhalation of the airborne substances. Exposure scenarios were developed based on a conservative estimate of potential human exposure, and based on accepted risk assessment practices. Exposure dose estimates were calculated for the potential exposure pathway based on estimated exposure point concentrations for each COPC.

Specific Exposure Scenarios

This risk assessment addresses the potential risk associated with residential exposure during a 30 year time period. The 30 year time period is the US EPA guideline used for residential risk assessments, since that is estimated to be the 95 % upper confidence limit of how long people live in a house. The US average is actually about 7 years. It was assumed, based on typical risk assessment protocols, that a person would be exposed as a child to the VOCs for 24 hours a day, 350 days a year, for 6 years, and then would be exposed as an adult for 24 hours a day, 350 days per year, for 24 years, for a combined exposure of 30 years. The attached Tables 1 and 2 provide the equations and assumptions for the residential exposures to the COPCs identified by the EarthRes Group. It was conservatively assumed that the exposures occurred at the point of the maximum concentration identified in the air monitoring. No attempt was made to average the air levels or to account for any dispersion that would occur between the sampling location and the exposure location. These equations allow for the calculation of the average daily dose used for the Non-carcinogenic assessment and the Lifetime Average Daily Dose used for the Carcinogenic assessment.

TOXICITY ASSESSMENT

This section presents toxicity criteria and information that relates constituent exposure (dose) to anticipated health effects (response) for each COPC. Toxicity criteria derived from dose-response data are used in the Risk Characterization section to estimate the carcinogenic risks, or non-carcinogenic hazard associated with exposure to these COPCs.

Toxicity criteria used in this risk assessment were obtained from US EPA's Integrated Risk Information System (IRIS) on-line database, PA DEP Guidance, other appropriate U. S. EPA guidance documents and the scientific literature, including the following sources:

- IRIS (US EPA, 2008);
- PA DEP Land Recycling Program Technical Guidance Manual – Section IV.A.4. Vapor Intrusion into Buildings from Groundwater and Soil under the Act 2 Statewide Health Standard
- Risk-Based Concentration Table Developed through an Interagency Agreement between EPA Office of Superfund and Oak Ridge National Laboratory (2008).

Table 3 presents available inhalation Cancer Slope Factors (CSFi) used to evaluate carcinogenic risk from inhalation exposure and Inhalation Reference Doses (RfDi) used to evaluate the potential non-carcinogenic hazard for all identified COPCs. Available inhalation unit risk factors were converted into inhalation slope factors, and Inhalation Reference Concentrations (RfCs) were converted into Inhalation Reference Doses (RfDi), in accordance with U. S. EPA guidance (1989). Where more than one toxicity factor was available from the identified sources, the most conservative value was selected for this evaluation (e.g., Ethylbenzene, Tetrahydrofuran and M,p Xylene).

Cancer Slope Factors, as developed by US EPA, are an indication of the potency of the specific chemical to induce cancer and are developed using conservative extrapolations from animal data or human data. For example, if the oral CSF was 1 mg/kg-day and the individual had a lifetime average daily exposure of 0.000001 mg/kg-day, the calculated risk would be one excess cancer in one million exposed individuals (0.000001 X 1). US EPA recognizes that these estimates are conservative and are actually upper-bound estimates of risk, and the true risk may be between the calculated value and zero.

Reference Doses (RfDs) are developed for Non-Carcinogenic effects by taking the No-Adverse-Effect-Level (NOAEL) and dividing by a series of Uncertainty Factors. The NOAEL is the dose from the animal or human study that results in no adverse health effects. The Uncertainty Factors are essentially safety factors, and can range from a total of 3 up to 10,000, depending on the nature of the study. In other words, EPA takes a dose that produces no or very minor toxicity and divides that dose by these safety factors to develop the Reference Dose. The RfD is described as an estimate of a daily exposure to the human population (including sensitive subgroups) that is unlikely to result in adverse health effects during a lifetime. The RfDs are used in determining the non-carcinogenic risk or hazard associated with chemical exposure. The lower the RfD of a substance the greater it's potential for toxicity or adverse health effects. As long as the average daily dose is below the RfD, no adverse health effects would be expected. For example if the RfD was 2 mg/kg/day and the average daily dose was determined to be 1 mg/kg/day, the calculated Hazard index would be 0.5. Since this value is less than unity, it indicates that adverse health effects would not be expected. Conversely, if the average daily dose was 2 mg/kg/day and the RfD was 1 mg/kg/day, the calculated Hazard index would be 2.0. Since this value is greater than unity, it indicates that there is a potential for adverse health effects.

RISK CHARACTERIZATION

In the final step of the risk assessment, the results of the exposure assessment (*i.e.,* the calculated intakes or doses) will be integrated with toxicity information, using U. S. EPA's current approach, to derive quantitative estimates of potential carcinogenic risk, or non-carcinogenic hazard, associated with the defined exposure scenarios. Risk estimates were calculated following the standard procedures defined in U. S. EPA's Risk Assessment Guidance for Superfund/Part A (U.S. EPA, 1989) and the results compared to levels of acceptable risk defined by U. S. EPA (U.S. EPA, 1990). The risk assessment will evaluate both the carcinogenic risk and non-carcinogenic hazard associated with the identified COPCs.

Carcinogenic risk was calculated for each carcinogenic COPC as a product of the constituent intake and the chemical-specific carcinogenic slope factor. The lifetime risk of developing cancer is calculated by multiplying the lifetime average daily dose by the corresponding cancer slope factor. Under each defined scenario estimated risks for each carcinogenic constituent will be summed to derive a total risk associated with a specific route of exposure (e.g., inhalation). The resulting risk is compared to acceptable levels of risk defined by U. S. EPA (1990) in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (*i.e.,* 1×10^{-6} to 1×10^{-4}) (one excess cancer in a million exposed individuals to one excess cancer in ten thousand exposed individuals). Pennsylvania DEP has determined that an excess cancer risk of 10^{-5}, or one in 100,000, is acceptable for individual constituents, and that the total site risk should not exceed 10^{-4} or one in 10,000. Also, all cancer Risk estimates are based on excess cancer risk, which is over and above the normal background lifetime level of cancer in the United States (currently approximately 33 per cent or 0.33). Accordingly, a one in a million cancer risk would increase that value to 0.330001.

The non-carcinogenic hazard, or hazard quotient, was calculated for each COPC by dividing the estimated daily dose by the identified RfD. Even though unwarranted, the total Hazard index was calculated by adding the individual Hazard quotients. The resulting Hazard Index is compared to the acceptable level for non-carcinogens defined by US EPA. As long as the total Hazard Index is less than 1.0, no adverse health effects would be expected. Even when the Hazard index exceeds one, it does not mean adverse health effects will occur, only that the potential for adverse health effects is present.

In this assessment, every attempt has been made to be conservative and, if anything, over estimate the potential risk. The conservative assumptions utilized in this analysis include:

1) maximum concentrations of each chemical were used in the analyses;

2) the exposure was continuous for 24 hours per day for 30 years;

3) the most conservative toxicity value was used for the analysis; and

4) no attempt was made to take into account dispersion from the sampling location to the potential resident.

RESULTS OF THE RISK ASSESSMENT

The following Tables provide the results of the risk assessments for the identified COPCs for the carcinogenic assessment and non-carcinogenic hazard associated with the constituents in the airborne samples in the ambient air around the Chrin Brothers Landfill. Only two of the constituents have been suggested to be potential carcinogens, and both are based on studies in animals. Neither Ethyl Benzene nor Tetrahydrofuran has been determined to produce cancer in humans. In addition, both of these compounds are controversial in terms of carcinogenicity and there is no uniformity among the agencies in their toxicity values.

Table 4 provides the potential carcinogen risk for the Child resident exposed to the airborne constituents found in the air monitoring study. The total carcinogenic risk for this exposure was 3.0 E-6, or 3 excess cancers per million exposed individuals. Neither of the two evaluated carcinogens exceeded the PADEP guideline of 1.0 E-05. Also as discussed above, there is controversy about the potential carcinogenicity of each of these chemicals.

Table 5 provides the potential carcinogen risk for the Adult Resident exposed to the airborne constituents found in the air monitoring study. The total carcinogenic risk for this exposure was 4.3 E-6, or slightly more than 4 excess cancers per one million exposed individuals. Also, neither of the two substances exceeded the PADEP guideline of 1 E-05.

Table 6 provides the potential Non-carcinogenic Hazard for the Child Resident exposed to the airborne constituents found in the monitoring study. The Total Hazard Index is 2.8 E-1, or 0.28, which is well below the acceptable level of 1.0.

Table 7 provides the potential Non-carcinogenic Hazard for the Adult Resident exposed to the airborne constituents found in the air monitoring study. The Total Hazard Index is 9.8 E-2, or 0.098, which is far below the acceptable level of 1.0.

Table 8 provides the summary of the carcinogenic risk and non-carcinogenic hazard associated with this assessment. When totaled the combined carcinogenic risk (adult plus child) is 7.3 E-06 or slightly more than 7 excess cancers in one million exposed individuals. These results assume that the individual (adult and child) would be exposed to the maximum levels identified, for 350 days per year for a total of 30 years, and that the cancer slope factors are the ones identified in Table 3. Similarly, the total hazard index (both adult and child) is 3.8 E-01, which is well below the guideline of 1.0, indicating that no adverse health effects would be expected.

A review of the available data indicates that the maximum concentration of most of the chemicals occurred at station # 3 or Station # 5. Station # 3 was located on the north end of the Landfill property and close to Interstate 78, while Station # 5 is located within a storage area on the east end of the landfill area. The two stations that would be most representative of potential residential exposure are Station # 6 located near the far eastern boundary of the Chrin Brothers Property, and Station # 7 located within the high-density residential area. The only chemical substance identified at either of these locations were Acetone, 2-butanone, ethanol and toluene, and the levels were about one-half of the maximum levels used in the risk analysis. A risk analysis conducted on either of these locations (i.e., the closest to the high-density residential areas) would result in a very low hazard index and no estimated increase in carcinogenic risk.

CONCLUSIONS

In summary, exposure to residential individuals over a 30-year time-frame would not be expected to encounter any unacceptable risk due to exposure to the COPCs identified in the airborne samples around the Chrin Brothers Inc. Sanitary Landfill. Specifically:

> *Using conservative assumptions for exposure, the evaluation of non-carcinogenic hazard indicates that the total hazard for the combined on-site and off-site receptors is less than 0.38, indicating that the exposure could be almost three times higher and still not be expected to produce any adverse health effects. The* two sampling locations closest to the

adjacent residential area did not have any detections of possible carcinogenic chemicals, and there is no elevated cancer risk downwind of the landfill. Wh*en evaluating the total carcinogenic risk, the total on-site and off-site risk is slightly more than seven excess cancers in a million exposed individuals, over a residential lifetime. This risk estimate, in addition to the current background, would mean that the total risk could increase from 0.33 to 0.3300073. This is an immaterial level of risk and acceptable under any standard or guideline.*

ABOUT THE AUTHOR

Gary Lage is currently a Principal of **ToxiLogics, Inc.** in Ewing, NJ, and has previously served as Senior Program Director and Senior Toxicologist for Environmental Resources Management, Inc. (ERM) in Exton, PA; as Principal and Senior Toxicologist at Environ, Inc.; and as a Vice President at Roy F. Weston, Inc. Before that I was Chairman of the Department of Pharmacology and Toxicology and Professor of Toxicology at the Philadelphia College of Pharmacy and Science. Prior to that I held teaching and research positions in pharmacology and toxicology at the University of Kansas and the University of Wisconsin. I hold a B.S. (1963) in Pharmacy from Drake University, and M.S. (1965) and Ph.D. (1967) in Pharmacology from the University of Iowa. As a toxicologist, I am one of approximately fifteen hundred diplomates of the American Board of Toxicology, Inc. indicating successful completion of the certification examination in general toxicology. I am a member of the Society of Toxicology, and the American Society for Pharmacology and Experimental Therapeutics. I have served as Chairman of the Toxics Health Effects Committee of the Department of Health of the Commonwealth of Pennsylvania, a Member of the Air Pollution Control Board of the City of Philadelphia, and as a member of the Vietnam Herbicide Information Commission for the Commonwealth of Pennsylvania. I served as the senior toxicology consultant for the State of Arizona when they were developing regulations for hazardous air pollutants. In addition, I have served on the Advisory Committee to the National Institutes of Environmental Health Sciences. I have recently served as a member of the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program for the National Research Council. Dr. Lage has been involved in evaluating the human health risks associated with VOCs in over a hundred different locations. (Curriculum Vitae attached as appendix B).

Selected References

Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles for Chemicals of Concern 2008

Environmental Protection Agency (EPA). Integrated Risk Information System (IRIS) Database, 2008

Oakridge National Laboratory Risk-Based Concentration Tables

Table 1 ***Inhalation Intake Factor Assumptions***

Child

Volatile Exposure

6 Year Exposure

$$\text{Dose} = \frac{Ca \times IR \times FS \times ET \times EF \times ED}{BW \times AT}$$

		Child Resident
Where:		
Dose		
Ca	= air concentration (mg/M3)	Chemical-specific
IR	= Inhalation rate (m3/hr)	0.5
FS	= Fraction of Site Contaminated	1
ET	= Exposure Time (hr/day)	24.00
EF	= Exposure frequency (days/yr)	350
ED	= Exposure duration (years)	6
BW	= Body weight (kg)	15
AT	= Averaging time (days)	
	Noncarcinogenic (AT= ED x 365)	2,190
	Carcinogenic (AT=70 yr x 365)	25,550
	Noncarcinogenic Oral Dose (mg/kg-day):	Chemical-specific
	Carcinogenic Oral Dose (mg/kg-day):	Chemical-specific

Table 3 ***Toxicity Values for Constituents of Potential Concern***

most conservative

	RfDi (mg/kg/d)		CSFi (kg-d/mg)	
Volatile Compounds				
Acetone	8.86E+00	o	NA	
2-Butanone	2.86E-01	p	NA	i
Carbon Disulfide	2.00E-01	o	NA	
Ethanol	NA	i	NA	i
Ethylbenzene	2.86E-01	o	8.75E-03	o
2-Propanol	NA		NA	
Tetrahydrofuran	8.60E-02	p	6.80E-03	p
Toluene	1.14E-01	p	NA	i
m,p-Xylene	2.86E-02	o	NA	

Notes:
i = IRIS, 2008 (Integrated Risk Information System)
o = ORNL tables
P = DEP Vapor Intrusion
NA = Not available.

RfDi = Reference Dose Inhalation
CSFi = Inhalation cancer slope factor.

Table 4 **Carcinogenic Risk due to Exposure to Volatiles in Air**

Resident

Child

Inhalation	**Exposure Concentration mg/M3**	**Exposure**	**Dose**	**CSFi**	**Risk**
Ethylbenzene	3.10E-03	6.58E-02	2.04E-04	8.75E-03	1.8E-06
Tetrahydrofurar	2.80E-03	6.58E-02	1.84E-04	6.80E-03	1.3E-06
				Total	3.0E-06

Table 5 **Carcinogenic Risk Inhalation of Volatiles in Air**
Adult

Inhalation	Exposure Concentration mg/M3	Exposure (Based on Equation)	Dose	CSFi	Risk
Ethylbenzene	3.10E-03	9.36E-02	2.90E-04	8.75E-03	2.5E-06
Tetrahydrofuran	2.80E-03	9.36E-02	2.62E-04	6.80E-03	1.8E-06
				Total	4.3E-06

Table 6 **Non-cancer Hazard due to Volatiles in Air**

Child

inhalation

Chemical	Exposure Concentration mg/L	Exposure (Based on Equation)	Dose	RfDi		Hazard
Acetone	1.60E-02	**7.67E-01**	1.23E-02	8.86E+00		1.4E-03
2-Butanone	8.40E-03	**7.67E-01**	6.44E-03	2.86E-01		2.3E-02
Carbon Disulfide	1.00E-02	**7.67E-01**	7.67E-03	2.00E-01		3.8E-02
Ethanol	1.20E-02	**7.67E-01**	9.21E-03	NA		
Ethylbenzene	3.10E-03	**7.67E-01**	2.38E-03	2.86E-01		8.3E-03
2-Propanol	7.30E-03	**7.67E-01**	5.60E-03	NA		
Tetrahydrfuran	2.80E-03	**7.67E-01**	2.15E-03	8.60E-02		2.5E-02
Toluene	7.60E-03	**7.67E-01**	5.83E-03	1.14E-01		5.1E-02
M,p-Xylene	4.80E-03	**7.67E-01**	3.68E-03	2.86E-02		1.3E-01
					Total	2.8E-01

Table 7 **Non-Cancer due to Exposure to Volailes in Air**

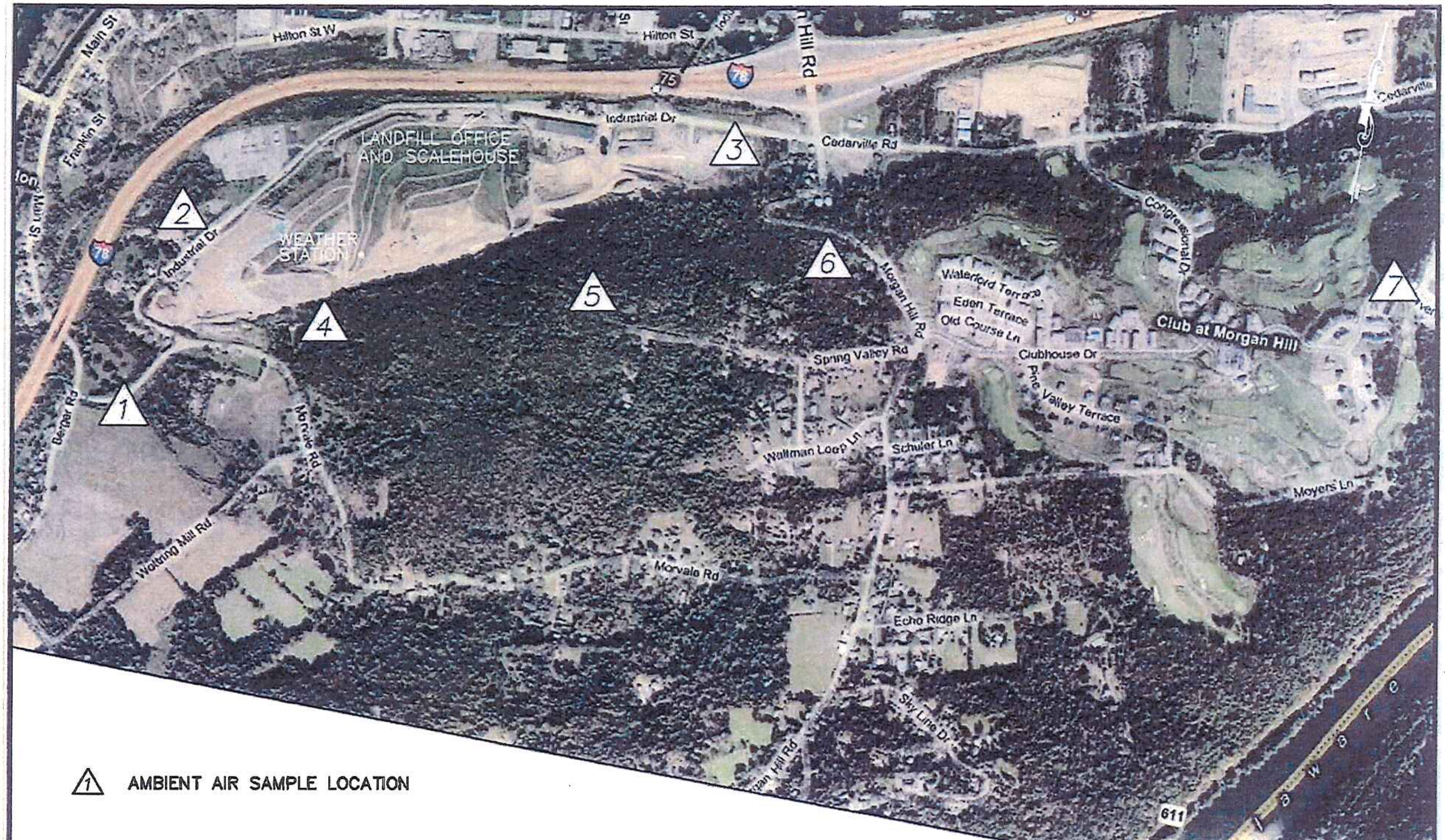
Adult

inhalation

Chemical	Exposure Concentration mg/M3	Exposure (Based on Equation)	Dose	RfDi		Hazard Quotient
Acetone	1.60E-02	**2.73E-01**	4.37E-03	8.86E+00		4.9E-04
2-Butanone	8.40E-03	**2.73E-01**	2.29E-03	2.86E-01		8.0E-03
Carbon Disulfide	1.00E-02	**2.73E-01**	2.73E-03	2.00E-01		1.4E-02
Ethanol	1.20E-02	**2.73E-01**	3.27E-03	NA		
Ethylbenzene	3.10E-03	**2.73E-01**	8.46E-04	2.86E-01		3.0E-03
2-Propanol	7.30E-03	**2.73E-01**	1.99E-03	NA		
Tetrahydrofuran	2.80E-03	**2.73E-01**	7.64E-04	8.60E-02		8.9E-03
Toluene	7.60E-03	**2.73E-01**	2.07E-03	1.14E-01		1.8E-02
m,p-Xylene	4.80E-03	**2.73E-01**	1.31E-03	2.86E-02		4.6E-02
					Total	9.8E-02

Table 8 **Summary of Carcinogenic Risk and Non-Carcinogenic Hazard**

Adult	**Harzard Index**	**Carcinogenic Risk**
Ambient Air	9.8E-02	4.3E-06
Child		
Ambient Air	2.8E-01	3.0E-06
Grand Total	3.8E-01	7.3E-06



△1 AMBIENT AIR SAMPLE LOCATION

IMAGE PUBLISHED BY:
UNITED STATES GEOLOGIC SURVEY (USGS)

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DATE: 03/19/09	PROJECT NO: 081022.002
DRAWING SCALE: 1" = 1200'	

FIGURE 2
AMBIENT AIR SAMPLE LOCATION PLAN

CHRIN BROS. SANITARY LANDFILL
WILLIAMS TOWNSHIP
NORTHAMPTON COUNTY, PA

GARY L. LAGE, Ph.D., DABT

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EDUCATION

1967	Ph.D., Pharmacology, University of Iowa
1965	M.S., Pharmacology, University of Iowa
1963	B.S., Pharmacy, Drake University

CERTIFICATION

Diplomate, American Board of Toxicology, 1980 - Present

EXPERIENCE

1996-Present	Founder, **ToxiLogics**, Inc., Ewing, NJ
1995-1996	Senior Program Director, Site Remediation, ERM, Inc., Exton, PA
1991-1995	Principal, Human Health Practice Area, ENVIRON Corp., Princeton, NJ
1987-1991	Project Director, Vice President and Practice Leader for Human Health Practice, Roy F. Weston, West Chester, PA
1984-1987	Philadelphia College of Pharmacy and Science, Chairman of the Department of Pharmacology and Toxicology Programs
1978-1984	Philadelphia College of Pharmacy and Science, Professor of Toxicology, Director of Toxicology Programs
1973-1978	University of Wisconsin-Madison, Associate Professor of Pharmacology and Toxicology

1972-1973 University of Kansas, Associate Professor of Pharmacology and Toxicology

1967-1972 University of Kansas, Assistant Professor of Pharmacology and Toxicology

Dr. Lage is a founding Principal of **ToxiLogics, Inc.**, responsible for incorporating current toxicology of chemicals and modern risk assessment into scientific decisions. He has over 30 years of experience in toxicology, both in its academic development as a scientific discipline and in consulting activities in risk assessment for industry and government. He has served as an expert in toxicology on numerous issues. He has experience in developing innovative solutions to environmental problems through the use of risk assessments, and is widely recognized for communicating complex issues of toxicology and risk assessment to nonscientific audiences. This activity has included the application of Risk-Based Corrective Action (RBCA) to environmental problems, and he has served as a trainer for ASTM RBCA E-1739-95. His work over the last decade has included the following:

- Served as an expert and conducted a risk assessment for reoccupation of a building that had been damaged by the September 11, 2001 collapse of the World Trade Center Towers.
- Provide a detailed summary of the toxicology of MTBE
- Been recognized as an expert in several hundred cases involving the toxicology of alcohol, including absorption, metabolism, and the physiological effects. These cases have included Dram shop cases, and criminal cases, including vehicular homicide.
- Been recognized as expert in cases involving the pharmacology and toxicology of drugs involving homicide and driving under the influence.
- Served as a toxicology expert in several cases involving potential health effects due to air emissions from various swine facilities.
- Served as a toxicology expert in a case involving prescription drug use and an aircraft accident.
- Conducted a risk assessment for a military installation involving the use of depleted uranium projectiles.
- Provided risk communication services to employees of several clients and potential chemical exposure.
- Developed a toxicology report agency submission for a pharmaceutical company based on an old toxicology study.
- Served as a toxicology expert in a case involving esophageal cancer and employment at a petroleum refinery.

- Served as a toxicology expert in a workers compensation case involving leukemia and chemical exposure.

- Served as a toxicology expert in a case involving an automobile accident and the influence of a dietary supplement on the driver.

- Provided risk communication to employees on health effects of asbestos associated with previous activities.

- Provided risk communication to employees on health effects of lead due to previous uses of the building.

- Consult on potential hazard within a day care center due to PCB contamination of an adjacent property.

- Served as a toxicology consultant in a matter involving the cleanup of several apartments that had been painted with paint containing tributyl tin.

- Served as a toxicology consultant in a case involving acute exposure to tetrachloroethylene due to a spill at a dry cleaner.

- Served as a toxicology expert involving death due to a drug overdose in prisoners.

- Assist client in development of guidelines for future development of former agricultural land to which historic pesticides had been applied.

- Served as toxicology expert in a case of alleged salivary gland cancer due to exposure to benzene.

- Provided Expert evaluation of tetrachloroethylene in relation to exposure to residences near dry cleaning establishments.

- Provided Expert evaluation of pancreatic enzyme preparations in response to alleged causation of fibrosing colonopathy

- Provides expert review of alternative cleanup levels for lithium

- Provide expert toxicology, risk assessment and risk communication services in numerous matters of potential indoor air exposure to chemicals (BTEX and Chlorinated hydrocarbons) in groundwater

- Provide expert toxicology and risk assessment assistance in a major sediment remediation project involving BTEX, PAHs and PCBs

- Provided toxicology and risk assessment services on several brownfields development projects (PA Act 2)
- Provided expert assistance in a decision to expand an major shopping mall onto property formally used as a petroleum tank farm
- Served on two Independent Review Teams for the US Army to evaluate environmental conditions on former army bases
- Served as an expert toxicologist in a case involving alleged health effects due to exposure to hair dyes
- Served as an expert toxicologist in a legal malpractice case involving bendectin
- Provided Risk assessment services on the future use of an abandon industrial property for residential development
- Provided expert toxicology and risk assessment services in several cases involving dieldrin
- Consulting on risk assessment activities associated with PCB contamination in the natural gas pipeline industry
- Provided Expert Report in case involving the toxicology testing for a pharmaceutical product
- Provided toxicology expertise and risk communication services in a case involving ground water contamination under homes
- Provided Expert Affidavit on the toxicological differences between hexavalent and trivalent chromium
- Provided Expert Opinion in a Worker's Compensation case involving pancreatic and stomach cancer
- Provided senior oversight to a human health risk assessment on the residual tars and petroleum hydrocarbons resulting from a fire of a petroleum tank farm. Substances included PAHs and BTEX.
- Provided toxicology expertise to determine cost apportionment for remediation of a landfill that contained municipal wastes and hazardous wastes.
- Served as a toxicology expert on a mercury spill within a school.

- Developed sediment remediation goals for an industrial river based on both human health and ecological risk analyses. The site involved PCBs, PAHs and metals.

- Developed assessment of risk to agricultural workers based on exposure to chemicals from nearby Superfund site.

- Developed support for no action alternative for soil remediation at a Superfund site.

- Evaluated the risk to the public from consumption of processed agricultural product grown in area with contaminated ground water and surface water.

- Evaluated the potential health effects to workers allegedly exposed to hydrogen sulfide.

- Directed a project to evaluate the human health impacts of consumption of PCB contaminated fish. Evaluation included conducting a fish survey to determine actual fish consumption and a survey of a local ethnic group to determine their consumption of preparation of fish from the river location.

- Participated in a major toxic tort case involving potential exposures to residents adjacent to a Superfund site.

- Participated as an expert toxicologist in a case involving exposure of residents to substances released from a specialty chemical company.

- Provided expertise in siting and permitting a commercial hazardous waste incinerator with development of a multiple pathway risk assessment and communication of results to regulatory agencies and public interest groups.

- Provided strategic guidance and expert evaluation in litigation involving chlorine and chlorine dioxide exposure to construction workers at a pulp and paper facility.

- Directed a TSCA 8(e) CAP audit for a major chemical manufacturer. In addition to developing a protocol for the audit, developed a database to assist the auditors and to assure retrieval of the over 10,000 studies reviewed.

- Reviewed a risk assessment for development of real estate on the shores of Lake Michigan to assure that the risk assessment would be acceptable to the lending and regulatory agencies.

- Evaluated the potential risks associated with a CFC substitute in foam insulation to workers or to residents of homes insulated with the product.

- Assisted a client in strategic planning for evaluating indoor air concentrations of off-site residences as a result of ground water contamination with volatile chlorinated organic hydrocarbons, and assisted in the protocol development and analysis of indoor air and interpreted the results for the corporation and the residents.

- Evaluated the potential risk to workers due to formaldehyde contamination of an agricultural product.

- Assisted a client in the strategic planning of protocol development and evaluation of potential indoor air contaminants at a former industrial facility due to ground water contamination with freon and chlorinated hydrocarbons, and presented the results to the current employees of the facility.

- Evaluated the potential adverse effects from dioxin contamination of naturally mined materials for both worker exposure and the exposure of consumers of products developed from these materials.

- Assisted a client in the strategic planning and site characterization for a Superfund site to assure that the sampling plan, analytical procedures, and detection limits would meet the needs of the risk assessment to be conducted for the site.

- Assisted four clients in developing protocol for TSCA 8(e) CAP audits.

- Assisted a client in negotiating a protocol for a risk assessment at a Superfund site to be performed by the EPA contractor to reduce the level of antagonism that might develop after the risk assessment was developed.

- Performed an updated risk assessment and evaluation of a Superfund site to incorporate current toxicology information and documented biodegradation into the risk assessment process.

- Assisted a client in designing and performing a risk assessment for a hazardous waste incinerator.

- Evaluated the hazards and potential liabilities for an insurance company due to an inappropriately applied pesticide in an apartment complex.

- Served as an international expert to review hazard assessments developed for 65 chemicals for the Ontario Ministry of the Environment.

- Assisted a client in evaluating potential off-site risks due to an industrial facility using 1,3-butadiene and incorporated current toxicological information on the mechanisms of toxicity of 1,3-butadiene.

- In a product liability case, evaluated the claim that a family was poisoned due to mercury contamination of a commercial juice product.
- Served as an expert toxicologist in litigation concerning trichloroethylene exposure due to contaminated ground water.
- Assisted in determining the necessity for a product recall due to a manufacturing error that caused significant quantities of alkaline material to be found in a consumer juice product. The product was recalled prior to any documented human exposure.
- Evaluated the potential risks due to chlorinated hydrocarbon contamination of ground water subsequently used in a consumer product.
- In a malpractice case, evaluated the potential adverse health affects from an alleged prescription error to the recipient.
- Assisted in performing multipathway risk assessments associated with post-remediation levels of PCBs in gas transmission locations.
- Served as project director and senior scientist for a hazardous waste incinerator project for a major chemical company that included a multipathway risk assessment, a traffic study, and a socioeconomic analysis.
- Performed several risk analyses to support a "no-action" alternative for ground water contaminants at contaminated industrial facilities.
- Served as an expert in support of a "no action" alternative for a site with complex cyanide contamination in soil. Involved differentiation of toxicity of simple cyanide compounds compared to complex cyanides.
- Served as senior scientist for an evaluation of the risk to pulp and paper facilities due to air emissions of chloroform. Developed scientifically sound alternative cancer potency values for chloroform, and presented assessments to numerous state and federal regulatory agencies.
- Directed a series of projects involving the determination of risk associated with PCBs in the gas transmission and distribution industries.
- Assisted a major metal processing facility in determining areas of maximum impact that would result from accidental chemical releases from the facility to surrounding residential areas. Determined which residential areas would be expected to experience illness or death due to worst-case chemical releases.

- Determined the potential adverse health impact to a sampling team at an NPL site due to unexpected exposure to dioxins, and communicated results to workers.

- Assisted a major company in developing risk-based environmental levels of lithium; helped negotiate with regulatory agencies concerning acceptable levels in ground water.

- Developed a computer model to predict off-site carcinogenic risks associated with on site air emissions; screening model utilized SARA Title III emissions information to predict the carcinogenic risk.

- Evaluated a risk assessment performed on a cement kiln designed to burn fuel derived from hazardous waste. Assisted in presenting results to the regulatory agency and throughout the litigation process.

- Directed the permitting process for a pulp and paper company seeking applicable air permits for a new facility.

- Performed an analysis and evaluation of occupational risks posed to workers in a PCB contaminated facility, and presented results to owners and workers.

- Evaluated potential carcinogenic risk to workers from long-term use of contaminated ground water at a metals manufacturing facility, and presented results to employers.

- Assessed indoor air concentrations and determined potential health risks in residences surrounding a petroleum pipeline leak; monitored indoor air and determined action levels for compounds such as benzene.

- Developed air quality guidelines for 99 toxic chemicals for the city of Philadelphia, one of the first municipalities to develop such guidelines in the early 1980s.

- Developed an educational program entitled "Toxicology for Non-toxicologists," presented widely to attorneys, environmental managers, and other audiences over the last fifteen years.

- For the Pennsylvania Department of Health, participated in a preliminary investigation of potential hazards from chemical waste sites to evaluate the need for a more extensive health assessment.

- Developed a "Chemical Education Hotline" to inform individuals and small businesses about chemical hazards in the workplace, with special emphasis on the OSHA Hazardous Communication Rule.

PROFESSIONAL MEMBERSHIPS AND ADVISORY POSITIONS

Member, Society of Toxicology; treasurer, 1985-1989.

Member, American Society of Pharmacology & Experimental Therapeutics.

Founder and First President, Mid-Atlantic Chapter, Society of Toxicology.

Member, American Industrial Hygiene Association

Member, American Chemical Society

Member, Society of Risk Analysis

Member, Society of Environmental Toxicology and Chemistry.

Member, International Society for the Study of Xenobiotics.

Member, American Association for the Advancement of Science.

Member, International Society of Regulatory Toxicology & Pharmacology.

Member, Drug Metabolism Group.

Member, Section of Toxicology of the International Union of Pharmacology (IUPHAR).

Adjunct Professor of Toxicology, Drexel University, 1985-1991, 1997 - Present.

Adjunct Professor, Allegheny University of the Health Sciences, 1997 – Present.

Lecturer, Pennsylvania State University, 1997 – Present.

Professor, Weston Institute, 1989-1993.

Member of Risk Assessment Subcommittee, and alternate to the Science Advisory Board for Pennsylvania Department of Environmental Protection, 1995-

Member, National Institute of Health, Environmental Health Sciences Review Committee, 1986-1990.

External Advisor, NIEHS Aquatic Biomedical Research Center, Medical College of Wisconsin, 1985-1988.

Member, Advisory Panel on Health, Safety, and Environmental Affairs, Smith Kline & French, 1984-1989.

Member, Advisory Committee on Toxic Air Pollutants for Philadelphia Department of Health, 1981-1987.

Member, Toxics/Health Effects Advisory Committee, Pennsylvania Department of Health, 1984-1988.

Member, Health Hazard Evaluation Panel, Weston, Inc., 1984-1987.

Member, Air Pollution Control Board, City of Philadelphia, 1983-1987.

Member, Board of Directors, Toxicology Laboratory Accreditation Board, Inc., 1983-1988.

Outside Reviewer, U.S. Navy Toxicology Program, 1983.

Member, Pennsylvania Vietnam Herbicide Information Committee, 1982-1987.

Member of the Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program for the National Research Council, 2000-2002.

PUBLICATIONS AND PRESENTATIONS

Lage, G.L. 2002. General principles of toxicology; Review of toxicological responses; and, Role of toxicology in risk assessment. Papers presented at the Government Institutes Symposium on Toxicology for Non-Toxicologists, Arlington, VA, April and November, 1993, Marino Del Ray, CA, July 1993 and July 1995; Santa Monica, CA, July 1994; Arlington, VA, April 1994, Hilton Head, S.C., July, 1992; Washington, D.C., April and November, 1992, November 1994, April, 1995; Richland, WA, November, 1991 and December 1992; Washington, D.C., October, 1995; October 1991; April 1991; October 1990; and April 1990; Toronto, Canada, June, 1995, Los Angeles, CA, July 1995, Alexandria, VA, October, 1995, Washington, DC, April 1996, Los Angeles, CA, July 1996, Washington, DC, November 1996, Washington, DC, May 1997, Los Angeles, CA, July, 1997, Washington DC, November 1997, Washington, DC, April, 1998, Redondo Beach, CA, July 1998, Arlington, VA, November 1998, Orlando, FL, February, 1999, Hilton Head, SC, June, 1999, Washington, DC, November, 1999; Hilton Head, SC, June 2000; Colorado Springs, CO, August 2000; Houston, TX, September, 2000; Washington, DC, November, 2000; Washington, DC, March 2001; Hilton Head, SC, July 2001; Washington, DC, November 2001; Orlando, FL, February 2002; San Francisco, CA, July 2002, Washington DC, November 2002, Scottsdale, AZ, March 2003, Hilton Head, SC, August 2003, New Orleans, LA, April 2004, and Hilton Head, SC, August 2004.

Lage, G.L., 2002, Drugs, Chemicals, Blood, Urine, Alcohol: The Toxicologist's Role in Presenting or Attacking Forensic Evidence, Presented at Pennsylvania Bar Institute 19th Annual Criminal law Symposium, Harrisburg, PA, April, 2002 and at Pennsylvania Bar Institute Afternoon of Criminal Law, Philadelphia, PA December 2002.

.Lage, G.L. Toxicology Training Course at Hazmat Conference, Las Vegas, NV, December 2001, and November 2003.

Lage, G.L. The Role of a Toxicologist in Criminal Cases, Presented at Pennsylvania Criminal Defense Lawyers Symposium, King of Prussia, PA, October 2001.

Lage, G.L. 1999, Presented two day course on Principles of Risk Assessment to Broward County Florida Environmental Department February 1999.

Lage, GL, 1999, Risk-Based Environmental Decision Making, Program Chairman and Major Speaker, Arlington, VA, September, 1998; Orlando, FL, April, 1999 and Washington, DC, September 2000..

Lage, G.L., 1998, Toxicology for Non-Toxicologists, Presented to Corporation, Cincinnati, OH, May 1998.

Lage, G.L., 1997, Toxicology for Attorneys, Presented to Law Firm, Santa Monica, CA, November 1997.

Lage, G.L., 1997, The Environmental Risk Institute, Program Chairman and Major Speaker, Alexandria, VA, September 1997.

Lage, G.L., 1996, Toxic Chemicals: The Dose makes the Poison, Presented to Trenton Section of American Chemical Society, November 1996.

Lage, G.L., 1996, The Risk Assessment Process, Application of ACT 2 Cleanup Goals, Evaluating Contaminant Transport & Ultimate Fate, Presented at Pennsylvania Council of Professional Geologists meeting on Pennsylvania's Land Recycling Program: Proposed Rulemaking for Risk-Based Corrective Action (RBCA) and the Implementation of Act 2, Philadelphia, October, 1996.

Lage, G.L., 1996, Risk-Based Corrective Action Wilmington, DE, May, 1996

Lage, G.L., 1996, ASTM Risk-Based Corrective Action Training, New York, March, 1996

Lage, G.L., 1996, Program Director and Major Speaker at The Environmental Risk assessment Course, Williamsburg, VA, December, 1995, Orlando, FL, March, 1996, Washington, DC, October 1996, and Annapolis, MD, April, 1997.

Lage, G.L., 1996 Total Cost Control for Remediation with ASTM E-1739-95, Philadelphia, March, 1996, Somerset, NJ, June, 1996.

Lage, G.L., 1996, Understanding Risk Assessments, Philadelphia, PA, December, 1995, and Pittsburgh, March, 1996

Lage, G.L., 1995, Current Applications of Risk Assessment, Presented at Forum on Michigan's New "Brownfields" Legislation, Lansing, MI, November, 1995

Lage, G.L. 1995 Risk Assessment: and Environmental Discussion, Presented to the Technology Council, Frazer, PA, October, 1995.

Lage, G.L. 1995. General principles of toxicology; Review of toxicological responses; and, Role of toxicology in risk assessment. Papers presented at the Governmental Institutes Symposium on Toxicology for Non-Toxicologists for U.S. Army Chemical Research, Development & Engineering Center, Aberdeen Proving Ground, Maryland, May, 1995, also presented in January 1992.

Lage, G.L The Changing Face of Risk Assessment in Environmental Decision making, Ohio Environmental Law Letter, Porter, Wright, Morris & Arthur, November, 1994.

Lage, G.L. The Changing Face of Risk Assessment as Applied to Environmental Decision making, Published in New Jersey Environmental Law Letter, Pitney, Hardin, Kipp & Szuch, October, 1994.

Lage, G.L. Environmental Risk Assessment Symposium for Government Institutes, Washington, DC, October, 1994.

Lage, G.L. 1994. Risk Assessments: Determining the Impact on Health and Environment, Presented at symposium entitled "Practical Environmental Science"; Government Institute, August 1994, October 1994.

Lage, G.L. 1994. Superfund: What's Needed and Why for the New York State Bar Association and Society for Risk Analysis. New York, New York. June 1994.

Lage, G.L. 1994. Site Remediation Issues in New Jersey After S-1070 for the Environmental Law Section of the New Jersey State Bar Association. Avalon, NJ. June 1994.

Lage, G.L. 1994. Risk Assessment of Incineration Products and Communication to the Public, Society of Toxicology. 6th Annual Meeting, Duquesne University, Pittsburgh, PA. May 1994.

Lage, G.L. 1994. Environmental Risk Assessment, Hoechst Celanese Corporation 1994 Environmental Health and Safety Conference, Charlotte, NC. May 1994.

Lage, G.L. 1994. Communication of Risk to the Public, Presented at Symposium on Incineration of Municipal Waste, Society of Toxicology Annual Meeting, Dallas, TX March, 1994.

Lage, G.L. 1994. Environmental Risk Assessment Symposium for Government Institutes, Orlando, FL March 1994.

Lage, G.L. 1993. Toxicology Update: Plaintiffs Targets in the 1990's, Presented at a symposium entitled Product Liability/Toxic Torts: Trends for the 90's, Philadelphia, PA October 1993.

Lage, G.L. 1993. Basics of Toxicology and Epidemiology, presented at symposium entitle The Science and Law of EMFs, Allentown, PA, June, 1993.

Lage, G.L. 1993. Environmental Risk Assessment Government Institute Symposium at Arlington, VA, 1993.

Lage, G.L. 1993. Symposium entitled Interfacing the Science of Toxicology with the Practice of Law, Presented at Princeton, NJ. February, 1993.

Lage, G.L. 1992. Lead Abatement Update, Presented at Symposium entitled Real Property and Environmental Liability, Alexandria, VA, October 1992.

Lage, G.L. 1992. Role of Risk Assessment in Superfund, presented at symposium entitled Environmental Regulations Houston, TX, September, 1992.

Lage, G.L. 1992. Methods to Conduct Risk Assessment, Presented at ILTA conference, Houston, TX, June, 1992.

Lage, G.L 1992. Environmental Risk Assessment: Techniques and Applications, Presented Government Institute Symposium, Arlington, VA, April, 1992.

Lage, G.L. 1992. Incorporation of Current Science into Risk Assessment, Presented at Mid-Atlantic Chapter of Society of Toxicology, Princeton, NJ April, 1992.

Lage, G.L. 1992. Drug toxicity. *The Merck Manual* 16th ed.

Lage, G.L. 1992. Methods to conduct risk assessments. Paper presented at the 12th Annual ILTA Operating Conference, Houston, Texas, June.

Lage, G.L. 1992. Environmental risk assessments: Techniques and applications. Paper presented at the Governmental Institutes Symposium on Environmental Risk Assessments, Arlington, Virginia, April.

Lage, G.L. 1991. The TSCA Compliance Audit Program: How to determine which studies to report under TSCA Section 8(e). Paper presented at the Government Institutes Symposium on the TSCA Compliance Audit Program, Arlington, Virginia, October.

Lage, G.L. 1991. TSCA 8(e) CAP audits. Paper presented at the 1991 Toxicology Roundtable Symposium, Long Branch, New Jersey, October.

Lage, G.L 1991. Risk assessment and its uses in environmental regulation. Paper presented at the Center for Energy and Environmental Management's Symposium on Risk Assessment, Alexandria, Virginia, October and May.

Lage, G.L. 1991. Risk assessment and how to cope with SARA Title III. Paper presented at the Pennsylvania Chamber of Business and Industry, Harrisburg, Pennsylvania, May.

Lage, G.L. 1990. Introduction to risk assessment -- dispersion modeling/risk assessment. Paper presented at Clean Air Engineering, Chicago, December.

Lage, G.L. 1990. Causation: Chemically induced disease -- the role of toxicology. *The Legal Intelligencer,* Philadelphia, November 15.

Lage, G.L. 1990. PCB management training. Paper presented to the City of Austin Power and Light, Austin, Texas, October.

Lage, G.L. 1990. The role of risk assessment in evaluating human health impacts of site clean-up alternatives. Paper presented at the Institute for International Research Symposium on Environmental Regulations at Federal Facilities, Washington, D.C., September.

Lage, G.L. 1990. Review of chloroform toxicology. Paper presented to the Environmental Committee of the Alabama Pulp and Paper Industry, Montgomery, Ala., September.

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Lage, G.L. 1989. Toxicity assessment; and Characterization of risk. Papers presented at the Government Institute Symposium of Environmental Risk Assessment, Washington, D.C., November.

Lage, G.L. 1989. Basic principles of toxicology. Paper presented at the Environmental Engineering Conference, University of Minnesota, Minneapolis, October; and at the Champion International Environmental Forum, Lake Logan, N.C., September.

Lage, G.L. 1989. Risk assessment methodology: Toxicological applications and limitations. Paper presented at the Symposium on Risk Assessment of Solid Wastes at the American Institute of Chemical Engineers, Philadelphia, Pa., August.

Lage, G.L. 1989. Impact of air toxics regulation on industry. Paper presented at Hazmat International, Atlantic City, N.J., June.

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Cannon, J.R., P.J. Harvison, and G.L. Lage. 1988. Age related differences in the metabolism of allyl alcohol to acrolein by Sprague-Dawley rats. Abstracted in *Toxicologist* 8:267.

Lage, G.L 1988. Drug testing: Causation implications. Paper presented to the Defense Research Institute Symposium on Workers Compensation, New York, December.

Lage, G.L 1988. Models of immune system testing. Paper presented to Annual Education Seminar of the Dermal Clinical Evaluation Society, Atlantic City, N.J., September.

Lage, G.L. 1988. Risk assessment and facility siting. Paper presented at the Government Institute Symposium on Incineration and Thermal Destruction of Hazardous Wastes, Philadelphia, Pa., July.

Lage, G.L. 1987. Drug toxicity. *The Merck Manual.* 15th ed.

Abdelhamid, S., V. Valez, D. Smallwood, and G. Lage. 1987. Toxicological risk assessment at hazardous waste sites: An engineer's perspective. Third Annual Hazardous Materials Management Conference West.

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