Health Consultation

CROWN MARKET

Public Health Implications of Indoor Air Residential Exposures Via Vapor Intrusion and Outdoor Occupational Exposures Via Soil Vapor

Evaluation of Former Leaking Underground Storage Tanks at Crown Market

DENVER, DENVER COUNTY, COLORADO

JUNE 12, 2007

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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DENVER, DENVER COUNTY, COLORADO

Prepared By:

Colorado Department of Public Health and Environment
Under Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

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Foreword

The Colorado Department of Public Health and Environment's (CDPHE) Environmental Epidemiology Section has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the US Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures so that the state or local department of public health can respond quickly to requests from concerned citizens or agencies regarding health information on hazardous substances. The Environmental Epidemiology Section (EES) evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur in the future, reports any potential harmful effects, and then recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and should not necessarily be relied upon if site conditions or land use changes in the future.

For additional information or questions regarding the contents of this health consultation or the Environmental Epidemiology Section, please contact the authors of this document:

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Summary and Statement of Issues

The purpose of this document is to identify any potential public health implications resulting from current and future exposures to the Crown Market Site plume of gasoline that extends under a residential community and child care facility and recommend actions to reduce the exposure, if necessary. The Department of Environmental Health of the City and County of Denver requested assistance from the Environmental Epidemiology Section (EES) to evaluate the potential public health hazards with respect to existing indoor air contamination via vapor intrusion into homes, businesses, and the child daycare facility.

The Crown Market Store Site was constructed in the early 1980's and operated as a gas and convenience store until 1990. In 1997, groundwater-monitoring wells were installed and gasoline impacts to the soil and groundwater were detected on site. The underground storage tanks leaked an unknown quantity of gasoline over a 20-year period of time. The area surrounding the site is largely residential with a small number of potentially impacted businesses. The shallow groundwater and very high dissolved benzene levels created a significant concern for potential benzene exposure via vapor intrusion into homes and businesses.

Much remediation has already taken place. The Colorado Division of Oil and Public Safety (OPS) is currently conducting cleanup of the contamination originating from the site. Approximately 4,716 cubic yards of contaminated soil was removed from the site in January 2001. More recently, OPS has worked with a nearby daycare to address their concerns about contamination of the indoor air and to remediate subsurface soils as the day care planned to install a basement. As such, the most recent monitoring data indicate that contamination levels are decreasing.

After a thorough review of the available indoor air data down gradient of the Crown Market Site, it is concluded that the exposures to benzene in the daycare are considered to pose no apparent public health hazard for current and future exposures. The past exposures (2004-2005) to benzene in the residential building are considered to pose a public health hazard based on the 2005 data. OPS and its contractor CGRS, Inc. have made multiple attempts to obtain additional sampling data at this residential building. However, the residents have denied access for additional sampling. As remediation is ongoing, it is likely that levels of contamination in the area have decreased. Therefore, the residential building is considered to constitute an indeterminate public health hazard for all current and future exposures until further indoor air sampling is conducted. The outdoor occupational exposures to utility workers in a trench through benzene in the soil vapors are considered to pose no apparent public health hazard. Overall, remediation is ongoing at the site and thus levels of contamination in the area are expected to decrease over time.

Background

Site Description and History

The Crown Market Site is located at 14125 E. 52nd Avenue within the northeastern corner of the City and County of Denver (the City) (Figures 1 and 2). The Crown Market Site was constructed in the early 1980's and was operated as a gas and convenience store until 1990. In October 1990, Law Engineering conducted an investigation that documented gasoline impacts to the soil and groundwater. When the ownership changed in 1994, the owner ceased operation of the three 10,000-gallon underground storage tanks (USTs) but continued operation of the convenience store (OPS, 2005).

Although the exact timing and quantity of gasoline leaked are unknown, Colorado Division of Oil and Public safety (OPS) concluded that significant quantities have been released over a 20-year period. The gasoline released from the Crown Market Site has migrated 600-700 feet to the northwest beneath a daycare and several adjacent homes. In summary, there are gasoline-impacted soils, soil vapors, and groundwater beneath the Crown Market Site, the daycare, and surrounding properties in the neighborhood. The concentration of benzene in groundwater beneath the daycare property was as high as 42,661 ppb (OPS, 2005). The gasoline-impacted soil is at a depth greater than 9 feet below ground surface (OPS, 2005).

In May 1997, groundwater-monitoring wells were installed on Crown Market property and on the vacant lot located just north of the site. Again, gasoline impacts to the soil and groundwater were documented. In November 1998, the three USTs, pump island, and canopy were removed from the site. New USTs, pump islands, and a canopy were installed in May 2001 (OPS, 2005).

In order to address the remaining contamination on site and offsite in the down-gradient direction, the owner submitted a Corrective Action Plan (CAP) to the OPS in September 2001. OPS did not approve this CAP because it was insufficient to clean up the high concentrations of gasoline contamination in soil, groundwater, and soil vapors. As such, OPS has been conducting the cleanup of the contamination originating from the site since September 2002 (OPS, 2005).

Between May 1997 and June 2004, thirty groundwater-monitoring wells were installed on site and in surrounding neighborhoods by an OPS contractor, CGRS, Inc. Soil vapor monitoring points were similarly installed. By the end of January 2001, 4,716 cubic yards of gasoline-impacted soil were excavated from the site and disposed of at BFIs Tower Road landfill in Adams County, Colorado (OPS, 2005). The excavation was backfilled with recycled concrete and clean fill material (OPS, 2005).

The shallow groundwater and very high dissolved benzene levels created a significant concern for potential benzene exposure via vapor intrusion into homes and businesses. Well water searches in the area indicate that there are no domestic wells within or near the gasoline impacted groundwater. The City serves all homes and businesses with municipal water. OPS and its contractor CGRS recommended remediation for soil and groundwater near an off-site daycare.

The proposed remediation included utilities to remove dissolved and vapor phase gasoline contamination, plus soil venting wells to remove soil vapors from the subsurface (OPS, 2005).

Vapor intrusion pathway

Many chemicals in unleaded gasoline evaporate readily into the air. For example, various combinations of benzene, toluene, ethylbenzene, and xylene (BTEX) are among the most frequently found mixtures in completed exposure pathways at gasoline-contaminated hazardous waste sites. BTEX belong to a class of organic compounds called volatile organic compounds (VOCs). VOCs have high vapor pressures that enable their vapors to readily enter the atmosphere. Vapor intrusion refers to the migration of VOC vapors from a subsurface zone into homes and buildings where people can be exposed. Subsurface sources can include contaminated groundwater and/or soils. Typically, vapors migrate through soils into indoor air spaces of overlaying buildings (EPA, 2006).

It should also be noted that site-related contamination is not the only source of BTEX in indoor air. BTEX are also present in many household sources including building materials, cleaners, furniture treatments, paint, plastics, sealants, cosmetics, and glues. For example, smoking indoors increases BTEX levels in indoor air. In general, studies have found that the levels of VOCs in indoor air are higher than in outdoor air (EPA, 2006). The contribution of BTEX from household sources to the overall indoor air concentration of BTEX introduces a level of uncertainty to the analysis of indoor air samples since it is often difficult to define the contribution of BTEX from each source.

Site visit

EES staff visited the site with a representative from the City in March 2007. Site access was granted by the operator of the daycare. EES staff participated in a walk-through of the daycare facility, the area near the residential building, Crown Market, and the adjacent neighborhood. The following observations were made:

- Crown Market was functioning as a convenience store.
- The daycare facility is a converted one-story house with several rooms and a small outdoor playground. The crawl space is approximately 5 feet tall with a dirt floor and is accessed only by adults through a hatch in the floor.
- The residential building is a single family house that has been converted to ‘apartments’ to accommodate a larger number of residents, and the access into the building was denied. There were often 3-4 cars parked outside each single family home in the immediate area. This is suggestive of high occupancy within these homes.
- No construction or utility work was observed in the immediate area.

Demographics

The demographic data listed herein is U.S. Census 2000 data from the census tract where the Crown Market site is located (83.11). In 2000, the census tract had a population of 8,637 – 4,268 (49%) females and 4,369 (51%) males. The median age was 27 years. Thirty-seven percent of the population were under 18 years old and 3 % were 65 years and older. In 2000, there were 2,492 households in the census tract. The average household size was 3.47 persons. Within the census tract, for people reporting one race, 28 percent were White alone; 44 percent were Black or African American; 1 percent were American Indian and Alaska Native; 4 percent were Asian. Five percent reported two or more races. Thirty-four percent of the people in the census tract were Hispanic or Latino. Twenty percent of the people living in the census tract were foreign born. Among people at least five years old, 31% speak a language other than English at home.

Community Health Concerns

Few community members have voiced health concerns about the need for indoor air sampling or the potential health effects resulting from the exposure to contaminated indoor air. Previous efforts to measure levels of contamination in indoor air in homes largely failed because the residents prohibited access and installation of monitoring devices.

All community involvement activities and the collection of community concerns are under the leadership of the City. The City has established a liaison in a community church and has been using this liaison as the primary means of communication with the potentially affected community. This liaison helps provide culturally competent communication, particularly to the portion of the community that is Spanish speaking. However, the community is largely reluctant to invite any intervention or activities conducted by either OPS or the City. Overall, community concerns remain unevaluated.

Discussion

Environmental Sampling and Data Used for Exposure Evaluation

The available data utilized in this evaluation include soil vapor, indoor air, and outdoor air samples taken by CGRS, Inc. and Summit Scientific, contractors to OPS and the City (CGRS, 2006b; Summit Scientific, 2007). The available data for the contaminated groundwater and soils are not discussed in this evaluation because exposures to these media are considered to represent an incomplete exposure pathway. The results of the sampling analysis and summary statistics for the data used in this evaluation are presented in Appendix Tables B1 to B4 and briefly discussed below.

Soil vapor samples were obtained from soil vapor implant wells installed at depths ranging between 4 and 9.5 feet. Soil vapor data was available from 2004-2006 at soil depth intervals of 4

feet and 9 feet (Appendix Tables B1). Only the 30 samples collected in 2006 will be used in this evaluation so that the future risk to utility workers can be best described. Twelve of the 30 samples were collected at 4 feet below the surface; 18 samples were collected at 9 feet below the surface.

The indoor air samples were collected using EPA methods, TO-14 and TO-15, using Summa-polished stainless steel canisters with the air being drawn in at a continuous rate over a period of 24 hours. The indoor air sampling data were available from 2004-2005 for the residential building; 8 samples were collected on main level and basement of the building (Appendix Tables B2). The evaluation of indoor air within the residential building is based only on the 2005 data, the most recent available data, because the concentrations of contaminants have significantly increased since 2004. As access to conduct sampling in other private residences was denied, the extent of the potential exposure remains unknown and is not evaluated here.

The indoor air sampling data were available from 2004-2006 for the day care; 22 samples were taken on two levels (main level and crawl space) of the building (Appendix Tables B3). The evaluation of indoor air within the daycare building will be based on all sampling data available from 2004-2006. It should be noted that the crawl space exposure is considered an incomplete exposure pathway because there is no access to crawl space for daycare children or employees, and air data are used in this evaluation for illustration purposes only. Confirmation samples were taken in 2007 from the daycare facility and included one sample of methyl tertbutyl ether (MTBE) that was not previously sampled. It should be noted that MTBE was found at levels below detection limits and is not evaluated further.

The outdoor air samples (Appendix Table B4) collected for this evaluation are intended to distinguish between the concentration of BTEX from indoor and outdoor sources.

Exposure Evaluation

Selection of Contaminants of Potential Concern (COPCs)

The maximum detected concentration of benzene, toluene, ethylbenzene, and xylene was compared with conservative health based environmental guideline or Comparison Value (CV) to select COPCs for further evaluation of potential health effects. Exposures to contaminants below the environmental guidelines are not expected to result in adverse or harmful health effects. However, exceeding the CV does not necessarily indicate that the contaminant poses a public health hazard. The amount of contaminant, duration and exposure route, exposure probability, and the health status and lifestyle of the exposed individual are important factors in determining the potential for adverse health effects.

The health based environmental guideline or screening values utilized as CVs in this evaluation are the Environmental Protection Agency's Region 3 Risk-Based Concentration (RBCs), ATSDR's Chronic, Intermediate, and Acute duration Minimal Risk Levels (MRLs). EPA

Region 3 RBCs for carcinogenic compounds in ambient air are based on an age-adjusted exposure covering 30 years from the time of birth to the age of 30 with an exposure frequency of 350 days per year. The inhalation RBCs for carcinogenic contaminants indicate that no more than one theoretical excess cancer case out of one million would be expected from exposures to this concentration in air. ATSDR's CVs for non-carcinogenic health effects are based upon acute, chronic and intermediate-duration inhalation exposures. When a cancer and non-cancer CV exist for the same chemical, the lower of these values is used as a conservative measure.

The maximum detected concentrations of toluene, ethylbenzene, and xylene found in the indoor air samples during sampling in the vicinity of the Crown Market Store are well below ATSDR MRLs for non-carcinogenic health effects. No COPCs were retained based on the noncarcinogenic health effects. Therefore, non-carcinogenic health effects are not likely to occur from exposures to the levels of contaminants in indoor air encountered during this evaluation. However, benzene is retained as a COPC for carcinogenic health effects since it exceeds EPA Region 3 RBCs for carcinogenic health effects (Appendix Table B6). Additionally, benzene and xylene were retained as COPCs for the outdoor occupational exposure evaluation for utility workers in a trench (Appendix Table B5).

The Conceptual Site Model

The conceptual site model describes the primary contaminants of potential concern, contaminated sources, and the potential exposure pathways by which different types of populations (e.g. residents and outdoor workers) might come into contact with contaminated media. Exposure pathways are classified as either complete, potential, or eliminated. Only complete exposure pathways can be fully evaluated and characterized to determine the public health implications. A complete exposure pathway consists of five elements: a source, a contaminated environmental medium and transport mechanism, a point of exposure, a route of exposure, and a receptor population.

Residents in private homes and individuals who work in the daycare may be exposed to contaminated indoor air via the vapor intrusion pathway. Additionally, utility workers may be exposed to soil vapors while working in a trench. It is, however, important to note that exposures to benzene in a crawl space at the daycare facility represent an incomplete exposure pathway because daycare children and adults have no access to the crawl space. Other incomplete exposure pathways for all types of receptors (e.g., residents, construction/excavation workers, and maintenance workers) at the Crown Market Site include: (a) exposures to impacted soils at depth intervals greater than 12 feet; and (b) exposures to contaminated groundwater because of the availability of municipal water supply. The overall conceptual site model for all complete and potential pathways at the Crown Market Site is presented below.

Conceptual Site Model

Pathway Name	Exposure Pathway Elements						
	Source	**Contaminated Envt'l. Medium**	**Point of Exposure**	**Potentially Exposed Population**	**Route of Exposure**	**Time Frame**	**Pathway Complete?**
Indoor Air	Leaking Underground Storage Tank (UST)	BTEX in groundwater and soil vapor	Indoor Air	-Residents -Daycare children and employees	Inhalation	Present Future	Complete
Outdoor Soil Vapor	Leaking UST	BTEX in groundwater and soil vapor (4 and 9 feet deep)	Soil vapor in outdoor trench at 4 and 9 feet	Utility or other types of workers in a trench	Inhalation	Future	Potential

Public Health Implications

The purpose of this evaluation is to determine whether exposures to COPCs that exceed the CVs for indoor air and soil vapors exposure pathways might be associated with adverse health effects. This requires a calculation of site-specific exposure doses for an estimated duration of exposure on-site and comparison with an appropriate toxicity value (or health guideline). Benzene is selected as the only contaminant of potential concern for the indoor air evaluation of the residential and daycare buildings. Benzene and xylene are selected as contaminants of potential concern for the outdoor air evaluation of utility workers in a trench at the depth interval of 4 ft and 9 ft.

To calculate theoretical cancer risks for the indoor air pathway, the inhalation dose of benzene in the indoor air samples is multiplied by the cancer slope factor (or health guideline) in accordance with the EPA Region 3 Risk-Based Concentrations methodology. To calculate theoretical cancer risks for the soil vapor pathway for utility workers in a trench, the inhalation dose of benzene in a trench is multiplied by the cancer slope factor (or health guideline) using the trench worker risk based concentration. A more detailed description of these methodologies is available in Appendix C. The available toxicity values (or health guidelines) utilized here to evaluate the likelihood of possible cancer and noncancer effects are discussed in Appendix D. The results of health risk calculations are presented in Tables 1 and 2.

In the daycare building, the estimated theoretical cancer risk on the main level is 6.09E-06 (6 cancer cases per million person exposed), based on the 2004-2006 data. However, based on a single sample collected in 2007, the estimated theoretical cancer risk on the main level is 2.8E-05 (28 excess cases per million people exposed). These risk estimates for children and adults in the daycare do not appear to represent a significant theoretical cancer risk because these are conservatively calculated based on the exposure assumption of 24 hrs/day for 350 days/year over 30 years. It is unlikely that an employee or child would spend that amount of time in the daycare. For example, at the maximum detected benzene concentration of 6.5 $\mu g/m^3$ in 2007 at the main level, the estimated theoretical cancer risk for a daycare child is 3.8E-06 (7-fold lower) based on the exposure assumption of 8 hr/day for 350 days/year over 6 years. Overall, noncancer adverse health effects from exposure to benzene in indoor air at the daycare are not likely to occur because comparison of the 2007 maximum detected benzene concentration of 6.5 $\mu g/m^3$ at the main level to the ATSDR MRLs for chronic (365 or more days), intermediate (15-364 days), and acute (1-14 days) duration exposures yield HQs that are less than 1.0. It should be noted that the cancer risk estimates based on benzene concentration in crawl space are not discussed here because there is no access to crawl space for the daycare children and employees and the results in Table 1 are for illustrative purposes only.

In the residential building, the estimated theoretical cancer risk is 1.2E-04 (120 excess cancer cases expected per million people exposed). The predicted cancer risk estimates for the residential building are considered to pose a public health hazard over long-term exposures of 30 years, based on the latest available data for 2005. In general, CDPHE strives to achieve a target cancer risk level of $1 * 10^{-6}$ or no more than 1 excess cancer case out of a million people for all site-related environmental exposures. The USEPA considers a risk level of $1* 10^{-6}$ to $1* 10^{-4}$ as the acceptable range of risk. In considering the estimated theoretical potential carcinogenic health risk, it is important to note that remedial action to remove the source of contamination is ongoing. This will reduce the timeframe of exposure and, subsequently, the potential to experience adverse health effects. Additionally, the calculated indoor residential cancer risks are conservative and likely to overestimate the true cancer risk for any individual because the actual length of exposure to residents is significantly less than 30 years. Moreover, air sampling results are available over a short time period (2004-2005). Since no data are available after 2005, theoretical cancer risks for the current and future exposures are considered indeterminate. The noncancer intermediate and chronic Hazard Quotient (HQ) for benzene are 1.3 and 2.7, respectively, based on the ATSDR health guidelines (MRLs) and are slightly above the acceptable level of HQ of 1.0. However, the maximum detected indoor air concentration of 27.4 $\mu g/m^3$ is significantly below the intermediate Lowest-Observed-Adverse-Affect-Level (LOAEL) of 5832 $\mu g/m^3$ in mice and the chronic LOAEL of 97 $\mu g/m^3$ in humans. Additionally, the maximum detected benzene indoor air concentration of 27.4 $\mu g/m^3$ is below the EPA's health guideline (Reference Concentration; RfC) of 30 $\mu g/m^3$. Therefore, the potential noncancer adverse health effects from exposure to benzene concentrations in indoor air at the residential building are not likely to be significant.

For outdoor utility workers in a trench, the estimated theoretical cancer risks are 2.11 E-05 (21 cancer cases per million person exposed) and 8.41E-04 (841 cancer cases per million person exposed) at a depth of 4 feet and 9 feet, respectively, when the EPC is based on 100 times dilution (EPA, 2006b, see Appendix C for more details). The currently available data for soil

vapor used in this evaluation appears to represent a significant theoretical potential carcinogenic risk at the soil depth interval of 9 feet, based on the EPC of 4646.0 µg/m^3 (i.e., 100 times dilution). No noncancer adverse health effects are likely to occur from exposure to benzene and xylene concentrations at the depth interval of 4 feet and from xylene concentrations at the depth interval of 9 feet, based on the comparison with risk-based concentrations for utility workers provided in Appendix Table C.2. However, the potential noncancer hazards from exposures at 9 feet deep to benzene concentration of 4646.0 µg/m3 are considered to enter a range of potential concern based on the exceedance of the following health guidelines or the No-Observed-Adverse-Effect-Level (NOAEL): ATSDR's acute, intermediate and chronic MRLs; EPA's Reference Concentration (RfC); ATSDR's chronic NOAEL or Benchmark dose confidence level (Table 2). It is, however, important to emphasize that no LOAELs for benzene are exceeded for the soil vapor pathway. The health effects seen at EPA's LOAEL of 8200 µg/m^3 include decreased lymphocyte count in a human occupational inhalation study (EPA IRIS, 2003). The ATSDR's chronic NOAEL of 97 µg/m^3 is based on decrease in B cell counts in workers of shoe manufacturing industries in China as determined by benchmark dose modeling (ATSDR 2005). Overall, it is important to note that if the true dilution of benzene contaminated soil vapors with ambient air is between 100 and 1000 times, the theoretical cancer risks and noncancer hazards based on the EPC diluted 1000 times may more closely approximate the cancer risk and noncancer hazards at the soil depth interval of 9 feet. Moreover, the remedial action to remove the source of contamination is ongoing and there is no current exposure to utility workers via the soil vapor pathway. Thus, soil vapor pathway for the future utility workers in a trench is not considered to constitute significant cancer risks and noncancer hazards.

As mentioned earlier, there may be some uncertainty associated with the amount of benzene in indoor air, which is attributable to domestic sources. Moreover, benzene is ubiquitous in the atmosphere. It has been identified in outdoor and indoor air samples of both rural and urban environments (ATSDR, 2005). For example, benzene is a component of gasoline vapors or vehicle exhaust, cigarette smoke, wood smoke, paints, adhesives, and particle board. However, the available outdoor air data for the residential building as well as the daycare facility suggest that the concentration of benzene in the outdoor air is significantly lower than the indoor air concentrations (Appendix Table B7). Overall, it appears that contaminated groundwater beneath the residential building is affecting indoor air quality. Since, benzene is a known human carcinogen, no matter what the source, exposure to benzene should be minimized based on prudent public health practice.

Child Health Considerations

In communities faced with air, water, or food contamination, the many physical and behavioral differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and

for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children's health.

The health effects of BTEX on young children are generally thought to be similar to the effects on adults. However, it is not known whether children are more sensitive to the effects of BTEX than adults (ATSDR, 2005). In general, children could have larger exposures than adults because BTEX are heavier than air and occur near the floor and children breathe air that is closer to the ground. The developing fetus and infants are of special concern when considering exposures to BTEX at this site because of potential exposures at the daycare and in private homes. However, benzene is the only contaminant of potential concern at this site. The unique susceptibility of children to adverse health effects from benzene exposures was considered in this evaluation by utilizing the risk-based concentrations that account for time-weighted early life exposures (0-6 years) through the age of 30. Children can be affected by benzene exposure in the same way as adults. It is not known if children are more susceptible to benzene poisoning. However, benzene can cross the placenta and can also be excreted in breast milk. Animal studies have shown low birth weights, delayed bone formation, and bone marrow damage when pregnant animals breathed benzene (ATSDR, 2005).

Conclusions

The Crown Market Site is considered to represent no apparent public health hazard, for all current and future exposures, based on the available data for benzene in the indoor air at the daycare. At the residential building, the past exposures (2004-2005) to benzene are considered to pose a public health hazard based on the latest available data of year 2005. Recently, OPS and its contractor CGRS, Inc. have made multiple attempts to obtain additional sampling data at this residential building. However, the residents have denied access to OPS and City representatives for additional sampling. As remediation is ongoing, it is likely that levels of contamination in the area have decreased. Therefore, until the residential building can be resampled, it is concluded that this building constitutes an indeterminate public health hazard for all current and future exposures.

The outdoor occupational exposures to utility workers in a trench (at a depth of 4 or 9 feet) through benzene and xylene in the soil vapors are considered to pose no apparent public health hazard. However, the extent of mixing of soil vapors with ambient air in a trench exposure scenario for the utility workers causes uncertainty in the predicted cancer risks and noncancer hazards because no air models are available to predict the concentration of chemical vapors in a trench. Therefore, the risk estimates presented in this evaluation are derived semi-quantitatively, based on the assumption of 100-1000 times dilution, and may over or underestimate the actual risks to utility workers in a trench. Overall, levels of contamination in the area are decreasing as a result of ongoing remediation. Please see Appendix F for a description of ATSDR's public health hazard categories.

Recommendations

Based upon the data and information reviewed, CDPHE has made the following recommendations:

- OPS should continue ongoing remediation to further reduce levels of contamination and potential for future exposures.
- The City and OPS should continue to monitor indoor air quality of the daycare to ensure that children in the daycare are not exposed to elevated levels of VOC contaminated indoor air.
- OPS should continue to collect and monitor groundwater and soil vapor concentrations of BTEX.
- The City and OPS should continue to make an effort to gain access and permission to collect indoor air samples from the residential building and other private homes located directly above the plume.
- The City should implement appropriate safety measures for future utility workers to prevent exposures to site-related contaminants in soil vapors.

Public Health Action Plan

The public health action plan describes the actions designed to mitigate or prevent adverse human health effects that might result from exposure to hazardous substances associated with site related contamination. The EES at CDPHE and the City commit to do the following public health actions to reduce exposure to site related contamination:

- By request, EES will evaluate any additional data that may be collected in the future.
- Upon request, EES will collaborate with the City to conduct health education and outreach activities.
- EES will make this document available to the public through the EES website and through the information repositories located in the community.
- By request, EES will facilitate translation of this document into Spanish and will provide a Spanish language version on the website.

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References

Agency for Toxic Substances and Disease Registry (ATSDR 2004). *Interaction profile for Benzene, Toluene, Ethylbenzene, and Xylene (BTEX).* Available on the internet at: http://www.atsdr.cdc.gov/interactionprofiles/ip05.html, accessed March 2007.

Agency for Toxic Substances and Disease Registry (ATSDR 2005). *Toxicological Profile for Benzene.* Available on the internet at: http://www.atsdr.cdc.gov/toxprofiles/tp3.html, accessed March 2007.

Agency for Toxic Substances and Disease Registry (ATSDR 2000). *Toxicological Profile for Toluene.* Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp56.html, accessed March 2007.

Agency for Toxic Substances and Disease Registry (ATSDR 1999). *Toxicological Profile for Ethylbenzene.* Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp110.html, accessed March 2007.

Agency for Toxic Substances and Disease Registry (ATSDR 2005). *Toxicological Profile for Xylene.* Available on the Internet at: http://www.atsdr.cdc.gov/toxprofiles/tp71.html, accessed March 2007.

CGRS (2006a). *Remediation System Installation, Start-Up, and Quarterly Monitoring Event for the Division of Oil and Public Safety – Remediation Section. May 25,2006.*

CGRS (2006b). *Quarterly Monitoring Event for the Division of Oil and Public Safety – Remediation Section.* September 27, 2006.

Division of Oil and Public Safety (2005). *Letter to Early Success Academy.* January 7, 2005.

Google Earth. Aerial Photograph Outlining Approximate Location of Crown Market, accessed February 2007.

Summit Scientific (2007). *Analytical Results for Samples taken at Crown Market/ Early Success Academy*. February 19, 2007.

U. S. Census Bureau. *U.S. 2000 Census*. Available on the Internet at http://www.census.gov/main/www/cen2000.html, accessed February 2007.

U. S. Environmental Protection Agency, Region 3 (EPA 2006a). *Human Health Risk Assessment, Risk-Based Concentration Table;* last update October 2006. Available on the Internet at: http://www.epa.gov/reg3hwmd/risk/human/index.htm, Accessed February 2007.

U.S. Environmental Protection Agency, Integrated Risk Information System (EPA 2003). *Full IRIS Summary: Benzene*. Available on the Internet at: http://www.epa.gov/iris/subst/0276.htm. Accessed April 2007.

U. S. Environmental Protection Agency, (EPA 2006b). *Introduction to Indoor Air Quality, VOCs;* last update September 2006. Available on the Internet at: http://www.epa.gov/iaq/voc.html, Accessed February 2007.

Tables and Figures

Figure 1. Ariel Photograph Outlining Approximate Location of Crown Market, Google Earth

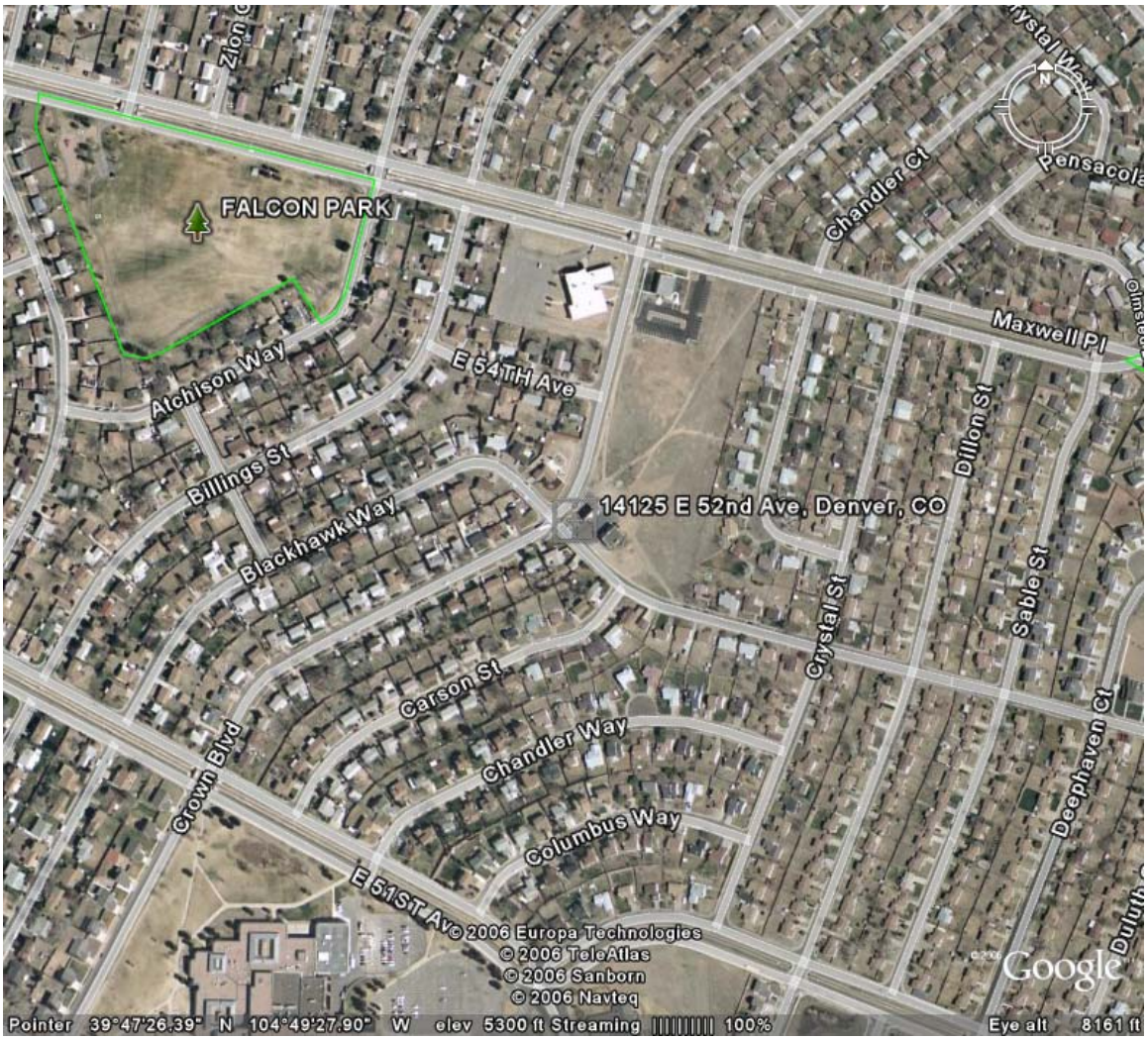

Figure 2. Map Outlining Approximate Location of Monitoring Wells, Crown Market, CGRS

Table 1. Theoretical Cancer Risk Estimates for Benzene in the Indoor Air of the Daycare and Residential Buildings

Location	Time period	EPC (µg/m3)	RBC (µg/m3)	Cancer Risk
Residential Building				
Main level	2005	26.80	0.23	1.17E-04
Basement	2005	27.4	0.23	1.19E-04
Daycare				
Main level	2004-2006	1.40	0.23	6.09E-06
Main level	2007	6.50	0.23	2.8E-05
Crawl space	2004-2006	1.84	0.23	8.0E-06 [a]
Crawl space	2007	15.00	0.23	6.5E-05 [a]

Note: the concentration of contaminants in the indoor air samples are divided by the EPA Region 3 Risk-Based Concentrations for benzene and then multiplied by $1*10^{-6}$ (i.e. 26.8 / 0.23 =116.5 * $1*10^{-6}$ = 1.17E-06)

[a] It should be noted that the cancer risk estimates based on benzene concentration in crawl space are for illustrative purposes only because there is no access to crawl space for the daycare children or employees and is considered an incomplete exposure pathway.

Table 2. Theoretical Cancer Risk Estimates and Non-cancer hazards for Outdoor Trench Workers Exposed to Benzene Contaminated Soil Vapor

Soil Depth	SVC (µg/m3)	EPC (SVC diluted by 100x)	Cancer RBC (µg/m3)	Cancer Risk	Noncancer RBC $_{\text{Health guideline}}$ (µg/m3)	Noncancer HQ $_{\text{Health guideline}}$	Noncancer HQ_{LOAEL}
4 feet	11,677.00	116.77	5.52	2.11E-05	183.11	0.6	N/A
9 feet	464,581.64	4,645.82	5.52	8.41E-04	183.11	25.4	0.09 [a]

Note: It should be noted that the cancer risk estimates and noncancer hazards (HQs) would be 10-fold lower at the EPC based on 1000x dilution of soil vapor concentration in a trench.

[a] HQ_{LOAEL} of 0.09 is calculated using the EPA IRIS selected LOAEL represented by the Benchmark Confidence Level (BMCL) of 8200 µg/m3 in humans, based on RBC_{LOAEL} of 49881.0 µg/ m^3. However, the ATSDR chronic MRL NOAEL is represented by the $BMCL_{0.25sd}$ of 97.0 µg/m^3 in humans (ATSDR, 2005) and results in HQ of 8.0, based on the RBC_{NOAEL} of 590.0 µg/m^3

APPENDICES

Appendix A. ATSDR Plain Language Glossary of Environmental Health Terms

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Additive Effect: A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

Antagonistic Effect: A response to a mixture of chemicals or combination of substances that is **less** than might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount of a chemical in a specific environment. Or, amounts of chemicals that occur naturally in a specific environment.

Bioavailability: See **Relative Bioavailability.**

Biota: Used in public health, things that humans would eat - including animals, fish and plants.

BTEX: Mixture of benzene, toluene, ethylbenzene, and xylene.

Cancer: A group of diseases, which occur when cells in the body become abnormal and grow, or multiply, out of control

CAP: Corrective Action Plan. A CAP is intended to document the recommendation for remedial actions at sites where petroleum releases have occurred, which are regulated by the Colorado Oil Inspection Section.

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

CDPHE: The Colorado Department of Public Health and Environment.

CERCLA: See **C**omprehensive **E**nvironmental **R**esponse, **C**ompensation, and **L**iability **A**ct.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

City (the): The City and County of Denver Department of Environmental Health.

Completed Exposure Pathway: See **Exposure Pathway**.

Comparison Value (CVs): Concentrations or the amount of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or worry that chemicals in the environment might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Delayed Health Effect: A disease or injury that happens as a result of exposures that may have occurred far in the past.

Dermal Contact: A chemical getting onto your skin. (See **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as "amount of substance(s) per body weight per day".

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

EES: Environmental Epidemiology Section within the Colorado Department of Public Health and Environment.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemical of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Exposure: Coming into contact with a chemical substance. (For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical.

ATSDR defines an exposure pathway as having 5 parts:

- Source of Contamination,
- Environmental Media and Transport Mechanism,
- Point of Exposure,
- Route of Exposure; and,
- Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, and twice a month.

Hazardous Waste: Substances that have been released or thrown away into the environment and, under certain conditions, could be harmful to people who come into contact with them.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

LOAEL: **L**owest **O**bserved **A**dverse **E**ffect **L**evel. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure - by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

MTBE: Methyl terbutyl ether.

NPL: The **N**ational **P**riorities **L**ist. (Which is part of **Superfund**.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

OPS: The Colorado Division of Oil and Public Safety, Department of Labor and Employment.

PHA: **P**ublic **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). Some examples include: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or the number of people in a certain area.

Public Health Assessment(s): See **PHA**.

Public Health Hazard: The category is used in PHAs for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each is defined in the Glossary. The categories are:

- Urgent Public Health Hazard
- Public Health Hazard
- Indeterminate Public Health Hazard
- No Apparent Public Health Hazard
- No Public Health Hazard

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, lifetime exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Relative Bioavailability: The amount of a compound that can be absorbed from a particular medium (such as soil) compared to the amount absorbed from a reference material (such as water). Expressed in percentage form.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:

- Breathing (also called inhalation),
- Eating or drinking (also called ingestion), and/or
- Getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

SARA: The **S**uperfund **A**mendments and **R**eauthorization **A**ct in 1986 amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Sample: A small number of people chosen from a larger population (See **Population**).

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors

(like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Superfund Site: See **NPL**.

Survey: A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.

Synergistic effect: A health effect from an exposure to more than one chemical, where one of the chemicals worsens the effect of another chemical. The combined effect of the chemicals acting together is greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's Public Health Assessment documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

UST: Underground Storage Tank.

Appendix B. Data Summary and Selection of Contaminants of Potential Concern (COPCs)

Table B1. Summary of available data for Soil Vapor Sampling

Medium	Location	Depth (Feet)	No. of Samples	Dates	Contaminants	Min Value (µg/m3)	Max Value (µg/m3)	Mean Value (µg/m3)	EPC (µg/m3)
Soil Vapor	All	4	31	2005	Benzene	<1	928,205	69,626.77	
					Xylene	<1	35,221	4,896.82	
					Ethylbenzene	<1	19,913	2,973.11	
					Toluene	<1	5,471	478.25	
			12	2006	Benzene	<1	11,677	4,002.36	11,677.00[2]
					Xylene	<1	11,952	2,107.49	9,360.44
					Ethylbenzene	<1	6,149	1,412.33	6,149.00[2]
					Toluene	<1	1,600	149.03	1,463.82[3]
Soil Vapor	All	9	26	2005	Benzene	<1	1,147,788	242,557.79	
					Xylene	<1	60,495	11,574.94	
					Ethylbenzene	<1	49,707	9,055.50	
					Toluene	<1	61,333	5,829.61	
			18	2006	Benzene	<1	487,913	130,000.11	464,581.64
					Xylene	<1	74,862	14,567.39	51,538.91
					Ethylbenzene	<1	55,603	10,871.77	35,391.17
					Toluene	<1	24,216	2,328.64	13,105.03[1]

Note: Unless otherwise stated, the Exposure Point Concentration (EPC) is the 95th percentile upper confidence limit (95% UCL) on the mean value based on 2006 data. Data are assumed to follow the normal or gamma distributions. Exceptions to this EPC calculation are as follows:

[1] **Non-parametric UCL – Halls Bootstrap 95% UCL**
[2] **The maximum value is selected as the EPC because the calculated UCL exceeds the maximum value**
[3] **Non-parametric – Chebyshev 95% UCL**

Table B2. Summary of Available Data for Indoor Air Sampling in the Residential Building

Location	No. of samples	Dates	Contaminants tested	Min Value (µg/m3)	Max Value (µg/m3)	Mean Value (µg/m3)	EPC (µg/m3)
Residential Bldg.							
Main level	3	2004	Benzene	3.20	10.80	6.17	
			Toluene	10.40	22.50	16.93	
			Ethylbenzene	1.20	3.50	2.43	
			Xylene	5.70	14.70	10.43	
	1	2005	Benzene	26.80	26.80	NA	26.80
			Toluene	89.20	89.20	NA	89.20
			Ethylbenzene	15.60	15.60	NA	15.60
			Xylene	79.60	79.60	NA	79.60
Basement	3	2004	Benzene	1.70	11.20	5.40	
			Toluene	10.00	23.70	11.67	
			Ethylbenzene	1.00	3.70	2.40	
			Xylene	4.70	15.50	10.13	
	1	2005	Benzene	27.4	27.4	NA	27.40
			Toluene	84.00	84.00	NA	84.00
			Ethylbenzene	14.30	14.30	NA	14.30
			Xylene	74.30	74.30	NA	74.30

Note: The EPC for the residential building represent the maximum value because there are fewer than 10 values.

Table B3. Summary of available indoor air sampling data for the daycare

Locations	No. of samples	Dates	Contaminants tested	Min Value (µg/m3)	Max Value (µg/m3)	Mean Value (µg/m3)	EPC (µg/m3)
Daycare							
Main level	3	2004	Benzene	0.88	1.42	1.10	
			Toluene	3.70	10.60	7.77	
			Ethylbenzene	<1.00	1.10	1.03	
			Xylene	3.00	4.60	3.70	
	5	2005	Benzene	0.55	2.40	1.14	
			Toluene	2.20	9.90	6.56	
			Ethylbenzene	<1.00	1.50	1.13	
			Xylene	1.30	5.50	3.30	
	3	2006	Benzene	0.69	1.29	0.95	
			Toluene	2.90	6.70	5.13	
			Ethylbenzene	<1.00	1.40	1.23	
			Xylene	2.50	5.80	4.67	
	11	2004-2006	Benzene	0.54	2.40	1.08	1.40
			Toluene	2.20	10.60	6.50	8.05
			Ethylbenzene	<1.0	1.50	0.99	1.23
			Xylene	1.30	5.80	3.78	4.64
Main level	1	2007	MTBE	<3.70	<3.70	<3.70	<3.70
			Benzene	6.50	6.50	6.50	6.50
			Xylene	59.00	59.00	59.00	59.00
			Ethylbenzene	6.70	6.70	6.70	6.70
			Toluene	27.00	27.00	27.00	27.00

Note: Exposure Point Concentration (EPC) for day care represents the 95th percentile upper confidence limit (95% UCL) on the mean value. The EPC for all 2007 samples at the daycare represent the maximum value because there are fewer than 10 values.

Table B3. Summary of available indoor air sampling data for the daycare cont'd.

Locations	No. of samples	Dates	Contaminants tested	Min Value (µg/m3)	Max Value (µg/m3)	Mean Value (µg/m3)	EPC (µg m3)
Daycare							
Crawl Space	3	2004	Benzene	0.94	1.81	1.38	
			Toluene	3.80	6.40	4.87	
			Ethylbenzene	<1.00	1.20	1.06	
			Xylene	3.40	5.10	4.00	
	5	2005	Benzene	<0.23	3.43	1.35	
			Toluene	1.90	9.80	4.74	
			Ethylbenzene	<1.00	1.80	1.17	
			Xylene	1.40	5.40	3.10	
	3	2006	Benzene	<0.23	1.05	0.66	
			Xylene	<1.00	4.50	2.53	
			Ethylbenzene	<1.00	1.00	0.99	
			Toluene Xylene	<1.00	4.60	2.66	
	11	2004-2006	Benzene	<0.23	3.43	1.17	1.84
			Toluene	<1.00	9.80	3.80	5.53
			Ethylbenzene	<1.00	1.80	1.09	1.23
			Xylene	<1.00	5.40	3.40	4.06
Crawl Space	1	2007	MTBE	<3.70	<3.70	<3.70	<3.70
			Benzene	15.00	15.00	15.00	15.00
			Xylene	6.90	6.90	6.90	6.90
			Ethylbenzene	<4.30	<4.30	<4.30	<4.30
			Toluene	7.60	7.60	7.60	7.60

Note: Exposure Point Concentration (EPC) for day care represents the 95th percentile upper confidence limit (95% UCL) on the mean value. The EPC for all 2007 samples at the daycare represent the maximum value because there are fewer than 10 values.

Table B4. Summary of Outdoor Air Data

Locations	No. of samples	Dates	Contaminants tested	Min Value (µg/m3)	Max Value (µg/m3)	Mean Value (µg/m3)	EPC (µg/m3)
Daycare	11	2004-2006	Benzene	0.38	2.74	1.24	1.62
			Toluene	1.2	7.9	3.59	5.04
			Ethylbenzene	<1	1.3	1.04	1.13
			Xylene	1.0	5.8	3.21	4.00
Residential Bldg.	1	2005	Benzene	7.85	7.85	7.85	7.85
			Toluene	20.3	20.3	20.3	20.3
			Ethylbenzene	3.9	3.9	3.9	3.9
			Xylene	13.9	13.9	13.9	13.9

Table B5. Selection of Contaminants of Potential Concern for Soil Vapor Pathway for Utility Workers in a Trench Using Environmental Comparison Values

Location	Time period	Chemical	Maximum soil vapor concn. (SVC) (µg/m3)	Maximum SVC diluted by 100x [a] (µg/m3)	CV (µg/m3)	COPC? (If Maximum concn. >CV)
Soil Vapor – 4 feet	2006	Benzene	11,677.00	116.77	0.23	Yes
		Toluene	35,221.00	352.21	5100	NO
		Ethylbenzene	6,149.00	61.49	1100	NO
		Xylene	1600.00	16.00	110	NO
Soil Vapor – 9 feet	2006	Benzene	487,913.00	4879.13	0.23	Yes
		Toluene	74862.00	748.62	5100	NO
		Ethylbenzene	55603.00	556.03	1100	NO
		Xylene	24216.00	242.16	110	Yes

[a] Represents maximum soil vapor concentration, based on the assumption of 100 times dilution, due to mixing of ambient air with soil vapor in a trench exposure scenario for utility workers.

Table B6. Selection of Contaminants of Potential Concern for Indoor Air Using Environmental Comparison Values

Location	Time period	Chemical	Maximum soil vapor concn. (µg/m3)	CV (µg/m3)	COPC? (If Maximum concn. >CV)
Residential Building					
Main level	2005	Benzene	26.8	0.23	Yes
		Xylene	79.6	5100	No
		Ethylbenzene	15.6	1100	No
		Toluene	89.2	110	No
Basement	2005	Benzene	27.4	0.23	Yes
		Xylene	74.3	5100	No
		Ethylbenzene	14.3	1100	No
		Toluene	84.00	110	No
Daycare Facility					
Main level	2004-2006	Benzene	2.4	0.23	Yes
		Toluene	5.8	5100	No
		Ethylbenzene	1.5	1100	No
		Xylene	10.6	110	No
Main level	2007	Benzene	6.50	0.23	Yes
		Toluene	27.00	5100	No
		Ethylbenzene	6.70	1100	No
		Xylene	59.00	110	No
Crawl space	2004-2006	Benzene	3.43	0.23	Yes
		Toluene	5.4	5100	No
		Ethylbenzene	1.8	1100	No
		Xylene	9.8	110	No
Crawl space	2007	Benzene	15.00	0.23	Yes
		Toluene	7.60	5100	No
		Ethylbenzene	<4.30	1100	No
		Xylene	6.90	110	No

Table B7. Selection of Contaminants of Potential Concern for Outdoor Air Samples Using Corresponding Environmental Comparison Values

Location	Time period	Chemical	Maximum Detected Conc. (µg/m3)	CV (µg/m3)	COPC? (If Maximum Conc.>CV)	EPC (µg/m3)
Residential Bldg.						
Outdoors	2005	Benzene	7.85	0.23	Yes	7.85[a]
		Xylene	13.9	5100	No	
		Ethylbenzene	3.9	1100	No	
		Toluene	20.3	110	No	
Daycare						
Outdoors	2004-2006	Benzene	2.74	0.23	Yes	1.64 [b]
		Toluene	7.9	5100	No	
		Ethylbenzene	1.3	1100	No	
		Xylene	5.8	110	No	

[a] Theoretical cancer risk for the outdoor air sample at the residential building at the EPC (maximum detected concentration) is 3.4E-05 (34 excess cancers expected per million people exposed).

[b] Theoretical cancer risk for the outdoor air sample at the daycare at the EPC (95 % UCL) is 7E-06 (7 excess cancers expected per million people exposed).

Appendix C. Exposure Parameters, Estimation of Exposure Dose, Derivation of Risk Based Concentration, and Risk Estimation

Estimation of Exposure Point Concentration

The Exposure Point Concentration (EPC) is a high-end, yet reasonable concentrations of benzene, toluene, ethylbenzene, or xylene that people could be exposed to based on the available environmental data. The standard procedure for calculating EPCs is to use the 95% Upper Confidence Interval on the mean of the data for each COPC. To calculate the EPC, the data was inserted into the EPA's statistical software package, ProUCL Version 3.02. The 2004-2006 data for indoor air in the daycare and the 2006 data for soil vapor were analyzed by this method and thus, the EPCs in these locations is the 95% UCL.

If the data is not normally distributed, ProUCL recommends an alternative value to use in lieu of the 95% UCL depending on the type of data distribution. One such alternative is to us the maximum value as the EPC when the calculated UCL exceeds the maximum value.

If there were less than samples available, the 95%UCL was not used to represent the EPC. The EPC for indoor air was not calculated by using the 95% UCL.

- Daycare building: The most recent (2007) data is treated separately from the 2004-2006 data. With only one sample taken in 2007, the EPC became the value of that measurement.
- Residential building: The most recent (2005) data was used to best estimate the current and future risks related to the contaminated indoor air. Measured concentrations increased between 2004 and 2005. With only one sample taken in 2005, the EPC became the value of that measurement.
- Soil Vapor in a trench for utility workers: The soil vapor concentration of benzene in a trench is diluted as a result of mixing with ambient air. Thus, a trench worker in this scenario would be exposed to a mixture of contaminated soil vapor and 'clean' ambient air rather than undiluted soil vapors. No EPA models are available to predict air concentrations in a trench. Therefore, risk has been calculated, semi-quantitatively, with the EPC diluted 100 times and 1000 times. This allows for a range of risks to better represent the uncertainty associated with mixing of air in a trench exposure scenario. The assumption of 100 to 1000-fold dilution is based on the 10-fold dilution factor from sub-slab soil gas to indoor air concentrations recommended by the EPA vapor intrusion guidance (EPA, 2006b).

Estimation of Exposure Dose and Risk Estimation

Exposure doses are estimates of the concentration of contaminants that people may come into contact with or be exposed to under specified exposure conditions. These exposure doses are estimated using: (1) the estimated exposure point concentration as well as the intake rate; and (2) the length of time and frequency of exposure to site contaminants.

Indoor Air Residential and Daycare Exposure Scenario

Occupants of the day care building and residents of the apartment building were assumed to be contaminated indoor air for 24 hours per day for 350 days per year for 30 years. It is unlikely that people will spend this much time in either structure and therefore the calculated risk estimates are conservative. Risks are calculated using EPA Region 3 RBCs available at http://www.epa.gov/reg3hwmd/risk/human/index.htm.

Calculation of the Noncancer hazard quotient (HQ) for Inhalation of Non-carcinogenic COC by Nearby Residents

$$\textbf{Noncancerous HQ} = \frac{\text{Indoor Air concentration (EPC)}}{\text{EPA Region 3 RBC}}$$

Calculation of Theoretical Cancer Risk for Inhalation of Carcinogenic COC by Nearby Residents

$$\textbf{Cancer Risk} = \frac{\text{Indoor Air concentration (EPC)} \times 10^{-6}}{\text{EPA Region 3 RBC}}$$

Utility Worker Trench Exposure Scenario

The site-specific information about the frequency and duration of exposure was used. Workers were assumed to be exposed to contaminated soil vapors for 8 hours per day, 60 days per year, for 10 years. The conservative assumption is based on the amount of time that a worker could spend in utility trenches or in basement or foundation construction in areas directly above the contaminated plume. This area is so small that exposure on this magnitude is highly unlikely. Therefore, risk estimates are likely to be conservative. The exposure parameters and risk-based concentrations for utility workers are provided in Tables C1 and C2, respectively.

Calculation of Worker Risk Based Concentrations for Inhalation of Non-carcinogenic COC

$$\text{Trench Worker Risk Based Concentrations (µg/m3)} = \frac{\text{AHQxRfDixBWxATxUCF}}{\text{IRxETxEFxED}}$$

Calculation of Outdoor Worker Risk Based Concentrations for Inhalation of Carcinogenic COC

$$\text{Trench Worker Risk Based Concentrations (µg/m3)} = \frac{\text{ARxBWxATxUCF}}{\text{IRxETxEFxEDxCSFi}}$$

Calculation of the Noncancerous hazard quotient (HQ) for Inhalation of Non-carcinogenic COC by Outdoor Workers

$$\text{Noncancerous HQ} = \frac{\text{Soil Vapor concentration (EPC)}}{\text{Non-cancer RBC}}$$

Calculation of Theoretical Cancer Risk for Inhalation of Carcinogenic COC by Outdoor Workers

$$\text{Cancer Risk} = \frac{\text{Soil Vapor concentration (EPC)} \times 10^{-6}}{\text{Cancer RBC}}$$

Table C.1 – Exposure Parameters for the Derivation of Utility Worker Risk Based Concentrations for Cancer and Noncancer Effects

Exposure / Intake Parameter	*Abbreviation*	*RME value*
Acceptable Hazard Quotient	**AHQ**	1
Acceptable Risk Level	**AR**	$1E^{-06}$
Averaging Time – carcinogenic	**AT_C**	25550 days
Averaging Time – non carcinogenic	**AT_{NC}**	3650 days
Body Weight	**BW**	70 kg
Cancer Slope Factor Inhalation	**CSFi** (From EPA Region 3 RBC table)	Benzene – 0.027 $(mg/kg\text{-}day)^{-1}$
Exposure Duration	**ED**	10 years
Exposure Frequency	**EF**	60 days/year
Exposure Time	**ET**	8 hours/day
Inhalation Rate	**IR**	2.5 m3/hour
Reference Dose Inhalation	**RfDi** (From EPA Region 3 RBC table)	Benzene - 0.0086 mg/kg-day
		Toluene – 1.4 mg/kg-day
		Ethylbenzene – 0.29 mg/kg-day
		Xylene – 0.03 mg/kg-day
Unit Conversion Factor	**UCF**	1000 µg/mg

Table C.2. Risk Based Concentrations for Utility Workers

Soil Depth	Chemical	Cancer RBCs (µg/m3)	Non-cancer RBCs (µg/m3)
4 feet	Benzene	5.52	183.11
	Toluene		29,808.33
	Ethylbenzene		6,174.58
	Xylene		638.75
9 feet	Benzene	5.52	183.11
	Toluene		29,808.33
	Ethylbenzene		6,174.58
	Xylene		638.75

Appendix D: Toxicological Evaluation

The basic objective of a toxicological evaluation is to identify what adverse health effects a chemical causes, and how the appearance of these adverse effects depends on dose. In addition, the toxic effects of a chemical frequently depend on the route of exposure (oral, inhalation, dermal) and the duration of exposure (acute, subchronic, chronic or lifetime). It is important to note that estimates of human health risks may be based on evidence of health effects in humans and/or animals depending on the availability of data. This evaluation, like most other toxicity assessments, is divided into two parts: the cancer effects and the non-cancer effects of the chemical.

EPA, IARC, and the Department of Health and Human Services have concluded that benzene is a human carcinogen. The Department of Health and Human Services determined that benzene is a known carcinogen based on human evidence showing a causal relationship between exposure to benzene and cancer. IARC classified benzene in Group 1 (carcinogenic to humans) based on sufficient evidence in both humans and animals. EPA classified benzene in Category A (known human carcinogen) based on convincing evidence in humans supported by evidence from animal studies. Under EPA's most recent guidelines for carcinogen risk assessment, benzene is characterized as a known human carcinogen for all routes of exposure. Based on human leukemia data, EPA derived a range of inhalation unit risk values of 2.2x10-6– 7.8x10-6 $(\mu g/m3)^{-1}$ for benzene. For cancer risks ranging from $1x10^{-4}$ to $1x10^{-6}$, the corresponding the corresponding air concentrations range from 13.0–45.0 µg/m3 (4–14 ppb) to 0.013–0.045 µg/m3 (0.004–0.014 ppb), respectively. The high-end unit risk factor corresponds to the cancer slope factor of 0.027 per mg/kg/day. The consensus conclusion that benzene is a human carcinogen is based on sufficient inhalation data in humans supported by animal evidence, including the oral studies in animals. The human cancer induced by inhalation exposure to benzene is predominantly acute nonlymphocytic (myelocytic) leukemia, whereas benzene is a multiple site carcinogen in animals by both the inhalation and oral routes (ATSDR, 2005).

The above noted high-end cancer slope factor is used to calculate EPA Region 3 Risk Based Concentrations (RBCs) that are used in this assessment to estimate risks. The RBC used in this assessment is based on age-adjusted theoretical cancer risks spanning 30 years from the time of birth to the age of 30. They account for exposure for 350 days per year over the thirty-year time period and lower body weights of children.

ATSDR has derived acute, chronic, and intermediate duration inhalational minimal risk levels (MRLs) or health guidelines to assess noncancer hazards. An MRL is the dose of a compound that is the estimate of daily human exposure that is likely to be without an appreciable risk of adverse non-cancerous health effects for each specified exposure duration. The acute, intermediate, and chronic MRLs address exposures of 14 days or less, 14-365 days, and 1 year – lifetime, respectively. For BTEX, there are additional considerations of noncancer toxicity. These chemicals can cause a wide range of symptoms that include dizziness, headaches, GI problems, anemia, kidney problems, and even death. For more detailed health information,

please see Appendix E for health effect fact sheets (Tox FAQs) on benzene the major chemicals of potential concern. The ATSDR MRLs and EPA RfC for benzene are noted below:

- Acute inhalation MRL = 30 µg/m^3
- Intermediate Inhalation MRL = 20 µg/m^3
- Chronic inhalation MRL = 10 µg/m^3
- EPA chronic inhalation RfC = 30 µg/m^3

Appendix E: ATSDR ToxFAQs for Benzene

BENZENE

CAS # 71-43-2

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES, Public Health Service

Agency for Toxic Substances and Disease Registry

Division of Toxicology and Environmental Medicine ToxFAQs™ September 2005

This fact sheet answers the most frequently asked health questions (FAQs) about benzene. For more information, call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. It is important you understand this information because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

HIGHLIGHTS: Benzene is a widely used chemical formed from both natural processes and human activities. Breathing benzene can cause drowsiness, dizziness, and unconsciousness; long-term benzene exposure causes effects on the bone marrow and can cause anemia and leukemia. Benzene has been found in at least 1,001 of the 1,662 National Priority List sites identified by the Environmental Protection Agency (EPA).

What is benzene?

Benzene is a colorless liquid with a sweet odor. It evaporates into the air very quickly and dissolves slightly in water. It is highly flammable and is formed from both natural processes and human activities. Benzene is widely used in the United States; it ranks in the top 20 chemicals for production volume. Some industries

use benzene to make other chemicals which are used to make plastics, resins, and nylon and synthetic fibers. Benzene is also used to make some types of rubbers, lubricants, dyes, detergents, drugs, and pesticides. Natural sources of benzene include volcanoes and forest fires. Benzene is also a natural part of crude oil, gasoline, and cigarette smoke.

What happens to benzene when it enters the environment?

Industrial processes are the main source of benzene in the environment.

Benzene can pass into the air from water and soil.

It reacts with other chemicals in the air and breaks down within a few days.

Benzene in the air can attach to rain or snow and be carried back down to the ground.

It breaks down more slowly in water and soil, and can pass through the soil into underground water.

Benzene does not build up in plants or animals.

How might I be exposed to benzene?

Outdoor air contains low levels of benzene from tobacco smoke, automobile service stations, exhaust from motor vehicles, and industrial emissions.

Vapors (or gases) from products that contain benzene, such as glues, paints, furniture wax, and detergents, can also be a source of exposure.

Air around hazardous waste sites or gas stations will contain higher levels of benzene.

Working in industries that make or use benzene.

How can benzene affect my health?

Breathing very high levels of benzene can result in death, while high levels can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. Eating or drinking foods containing high levels of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, and death.

The major effect of benzene from long-term exposure is on the blood. Benzene causes harmful effects on the bone marrow and can cause a decrease in red blood cells leading to anemia. It can also cause excessive bleeding and can affect the immune system, increasing the chance for infection.

Some women who breathed high levels of benzene for many months had irregular menstrual periods and a decrease in the size of their ovaries. It is not known whether benzene will affect fertility in men.

How likely is benzene to cause cancer?

Long-term exposure to high levels of benzene in the air can cause leukemia, particularly acute myelogenous leukemia, often referred to as AML. This is a cancer of the bloodforming organs. The Department of Health and Human Services (DHHS) has determined that benzene is a known carcinogen. The International Agency for Research on Cancer (IARC) and the EPA have determined that benzene is

carcinogenic to humans.

How can benzene affect children?

Children can be affected by benzene exposure in the same ways as adults. It is not known if children are more susceptible to benzene poisoning than adults.

Benzene can pass from the mother's blood to a fetus. Animal studies have shown low birth weights, delayed bone formation, and bone marrow damage when pregnant animals breathed benzene.

How can families reduce the risks of exposure to benzene?

Benzene exposure can be reduced by limiting contact with gasoline and cigarette smoke. Families are encouraged not to smoke in their house, in enclosed environments, or near their children.

Is there a medical test to determine whether I've been exposed to benzene?

Several tests can show if you have been exposed to benzene. There is a test for measuring benzene in the breath; this test must be done shortly after exposure. Benzene can also be measured in the blood; however, since benzene disappears rapidly from the blood, this test is only useful for recent exposures.

In the body, benzene is converted to products called metabolites. Certain metabolites can be measured in the urine. The metabolite S-phenylmercapturic acid in urine is a sensitive indicator of benzene exposure. However, this test must be done shortly after exposure and is not a reliable indicator of how much benzene you have been exposed to, since the metabolites may be present in urine from other sources.

Has the federal government made recommendations to protect human health?

The EPA has set the maximum permissible level of benzene in drinking water at 5 parts benzene per billion parts of water (5 ppb).

The Occupational Safety and Health Administration (OSHA) has set limits of 1 part benzene per million parts of workplace air (1 ppm) for 8 hour shifts and 40 hour work weeks.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological Profile for Benzene (Draft for Public Comment). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

Where can I get more information? For more information, contact the Agency for Toxic Substances and Disease Registry, Division of Toxicology and Environmental Medicine, 1600 Clifton Road NE, Mailstop F-32, Atlanta, GA 30333. Phone: 1-888-422-8737, FAX: 770-488-4178. ToxFAQs Internet address via WWW is http://www.atsdr.cdc.gov/toxfaq.html. ATSDR can tell you where to find occupational and environmental health clinics. Their specialists can recognize, evaluate, and treat illnesses resulting from exposure to hazardous substances. You can also contact your community or state health or environmental quality department if you have any more questions or concerns.

Appendix F: ATSDR Public Health Hazard Categories

Category / Definition	Data Sufficiency	Criteria
A. Urgent Public Health Hazard This category is used for sites where short-term exposures (< 1 yr) to hazardous substances or conditions could result in adverse health effects that require rapid intervention.	This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.	Evaluation of available relevant information* indicates that site-specific conditions or likely exposures have had, are having, or are likely to have in the future, an adverse impact on human health that requires immediate action or intervention. Such site-specific conditions or exposures may include the presence of serious physical or safety hazards.
B. Public Health Hazard This category is used for sites that pose a public health hazard due to the existence of long-term exposures (> 1 yr) to hazardous substance or conditions that could result in adverse health effects.	This determination represents a professional judgment based on critical data which ATSDR has judged sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.	Evaluation of available relevant information* suggests that, under site-specific conditions of exposure, long-term exposures to site-specific contaminants (including radionuclides) have had, are having, or are likely to have in the future, an adverse impact on human health that requires one or more public health interventions. Such site-specific exposures may include the presence of serious physical or safety hazards.
C. Indeterminate Public Health Hazard This category is used for sites in which "*critical*" data are *insufficient* with regard to extent of exposure and/or toxicologic properties at estimated exposure levels.	This determination represents a professional judgment that critical data are missing and ATSDR has judged the data are insufficient to support a decision. This does not necessarily imply all data are incomplete; but that some additional data are required to support a decision.	The health assessor must determine, using professional judgment, the "criticality" of such data and the likelihood that the data can be obtained and will be obtained in a timely manner. Where some data are available, even limited data, the health assessor is encouraged to the extent possible to select other hazard categories and to support their decision with clear narrative that explains the limits of the data and the rationale for the decision.
D. No Apparent Public Health Hazard This category is used for sites where human exposure to contaminated media may be occurring, may have occurred in the past, and/or may occur in the future, but the exposure is not expected to cause any adverse health effects.	This determination represents a professional judgment based on critical data which ATSDR considers sufficient to support a decision. This does not necessarily imply that the available data are complete; in some cases additional data may be required to confirm or further support the decision made.	Evaluation of available relevant information* indicates that, under site-specific conditions of exposure, exposures to site-specific contaminants in the past, present, or future are not likely to result in any adverse impact on human health.
E: No Public Health Hazard This category is used for sites that, because of the absence of exposure, do NOT pose a public health hazard.	Sufficient evidence indicates that no human exposures to contaminated media have occurred, none are now occurring, and none are likely to occur in the future	

Certification

This Crown Market health consultation was prepared by the Colorado Department of Public Health and Environment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved methodology and procedures existing at the time, the health consultation was conducted. Editorial review was completed by the cooperative agreement partner.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this health consultation, and concurs with its findings.

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