similar to that of radon gas seeping into homes, as shown in Figure 1. As the figure illustrates, this vapor intrusion pathway may be important for buildings both with and without a basement.

Many of the chemicals in unleaded gasoline evaporate readily into the air. For this reason, there is potential for chemicals to move from a site through groundwater or soil vapor and enter the indoor air of nearby structures. In this case, the First Methodist Church, the Wells Fargo Bank, North Valley Middle School, Mirich Elementary School, and at least two homes in the adjacent neighborhood were impacted by the UST leakage. All of these structures have had soil vapor extracting systems installed. Also, many monitoring wells have been placed in the neighborhood and numerous soil vapor samples have been taken.

Sampling Methods

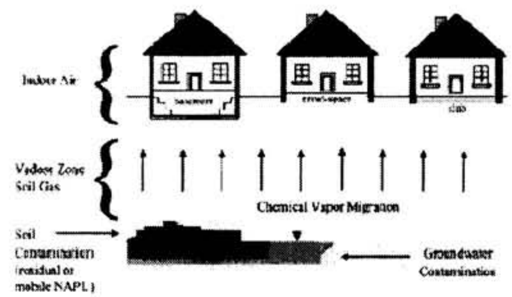

Figure 1: Generalized schematic of the pathway for subsurface vapor intrusion into indoor air.

As part of the remediation project, CGRS analyzed samples from numerous homes and buildings in the neighborhood near the Everyday Store. CGRS identified several contaminants related to the Everyday Store UST leak. The sampling was performed by taking a grab sample or a short-time-period sample known as a Tedlar sample. This sampling method, which takes a sample of air collected during a few minutes, pulls air into a Tedlar bag. In comparison, all of the other sampling followed EPA methods, TO-14 and TO-15 guidelines, using Summa-polished stainless steel canisters with the air being drawn in at a continuous rate over a longer period of time (8 or 24 hours). The advantage of a grab sample is that the sampling is quick and easy. The advantage of a long sample is that the sampling provides a more realistic characterization of what people may be exposed to. The advantage of a Tedlar bag is that the sampling is rapid and inexpensive. The advantage of a Summa canister is that it is less prone to gas diffusion from the container and to contaminant reactions with or adherence to the container walls.

The Tedlar method was used as a preliminary, quick measure to detect the contamination in indoor air. Once contamination was detected by the Tedlar sample method, further sampling was performed using either the 24- or 8- hour Summa method.

CGRS's monitoring activities indicate that several vapor contaminants are all components of unleaded gasoline. The CDPHE's initial screening of the laboratory vapor data included analyzing the Summa sample results from indoor air monitoring. If both a Tedlar grab sample and a Summa sample (24- or 8- hour) were taken from the same location, then the Summa sample became the default concentration value used, because generally a summa sample is a more accurate measure of the actual exposure. Summa samples are taken over a longer period of time; similar to the amount of time exposure would occur to a resident or occupant of a building.

Exposure Pathways and Contaminants of Concern

A completed exposure pathway exists when the five elements of a pathway link the contaminated source to a receptor population. Pathways for which the Everyday store contamination constitutes a potential source of exposure are depicted as follows:

Human Exposure Pathways					
Pathway Name	Environmental Medium	Point of Exposure	Route of Exposure	Exposed Population	Completed Pathway?
Indoor Air Vapor	Indoor Air Vapor	Everyday Store, nearby homes, &, other buildings	Inhalation	nearby residents (includes children) Students and Staff at the two nearby schools, and church	Yes
Groundwater	Groundwater	Everyday Store	Ingestion	all residents and buildings are linked to a municipal water supply. Therefore, there is no apparent exposure to groundwater	No

The Department of Public Health evaluated potential human exposure pathways associated with contaminants detected by CGRS at the Everyday store site. Based on the data provided, pathways evaluated in this consultation are associated with the vapors from the groundwater plume. Specifically, this pathway includes the inhalation of vapors through indoor air.

Studies by the U.S. Environmental Protection Agency have shown that most homes in the U.S. have measurable levels of organic chemicals in indoor air. While outdoor air contains many organic chemicals, a surprising finding from EPA studies throughout the U.S. is that the concentrations of organic chemicals in indoor air are usually higher than outdoor air. These higher indoor air levels of Volatile Organic Compounds (VOCs) presumably come from consumer products that are brought into the homes, from off-gassing of home building materials, and from personal activities. EPA studies showed that certain human activities were associated with having increased levels of chemicals in indoor air. Examples of these activities are listed below (EPA, 1987):

- smoking indoors increases benzene, xylene, ethylbenzene, and styrene levels in indoor air;
- bringing dry cleaning home causes higher PCE levels in indoor air;
- using hot water in the home increases chloroform levels in indoor air; and
- using room air fresheners, toilet bowl deodorizers, and moth crystals leads to higher levels of para-dichlorobenzene in indoor air.

Typically, gasoline contains more than 150 chemicals including small amounts of benzene, ethyl-benzene, toluene, and xylene. How the gasoline is made determines which chemicals are present in the gasoline mixture and how much of each is present. The actual composition varies with the source of the crude petroleum, the manufacturer, and the time of year. Gasoline is a colorless, pale brown, or pink liquid. Gasoline is very flammable and catches fire quite easily, evaporates quickly, and forms explosive mixtures with air. Most people can begin to smell gasoline at 0.25 parts of gasoline per million parts of air (ppm). Gasoline, which does not dissolve readily in water, may be present in the air, groundwater, and soil. However, some of the chemicals that make up gasoline can dissolve easily in water.

Findings

The results of this sampling are depicted in Table 1. Only benzene was detected at levels above a comparison value. The levels of benzene detected in the more than 170 Summa samples of indoor air from 28 residences, an elementary and middle school, and other buildings ranged from not detected (ND) to 24.07 micrograms per cubic meter ($\mu g/m^3$). In 17 of the 28 homes, benzene was detected in the air at levels above the health comparison value of 0.1 $\mu g/m^3$, which is ATSDR's cancer risk evaluation guide (CREG). None of the samples exceeded EPA's Reference Concentration (RfC) for benzene of 30 $\mu g/m^3$. As of February 2004, the monitoring report submitted to OPS suggests that the levels of benzene are below 6 $\mu g/m^3$ in all indoor air samples. The highest detected level of benzene in indoor air was 24.07 $\mu g/m^3$. This level was measured in a home after the occupants were evacuated and were living temporarily in a hotel. Approximately one week later, the measured benzene in the indoor air had dropped to 2.4 $\mu g/m^3$.

Table 1 – Contaminants Found in Residential Indoor Air

Chemical	Number of Samples	Range in micrograms per cubic meter ($\mu g/m^3$)	Comparison Values (CV) in $\mu g/m^3$	Source	Number of Samples above CV
Benzene	172	not detected to 24.07	0.1/30	CREG*/RfC§	165/0
Ethylbenzene	172	not detected to 17.4	1,000	RfC§	0
Toluene	172	not detected to 50.27	302†	EMEG & MRL‡	0
Xylene	172	not detected to 109	434€	EMEG & MRL‡	0

* CREG – ATSDR's Cancer Risk Evaluation Guide
§ RfC – EPA's Reference Concentration
† This is a conversion of the ATSDR EMEG & MRL of 100 ppb for toluene to $\mu g/m^3$ using the formula: concentration in $\mu g/m^3$ = concentration in ppb * molecular weight ÷ 24.45
‡ EMEG & MRL – ATSDR's chronic environmental media exposure guide and minimal risk level for air
€ This is a conversion of the ATSDR EMEG & MRL of 80 ppb for total xylene to $\mu g/m^3$ using the formula: concentration in $\mu g/m^3$ = concentration in ppb * molecular weight ÷ 24.45

Benzene is a component of gasoline emissions, cigarette smoke, paints and adhesives, particle board, wood composites, and wood smoke. The estimated average of the medians (50% values) for typical background levels found in several studies was reported to be approximately 6 $\mu g/m^3$, with generally higher levels found in homes with smokers (Wallace, L., 1996). However, it is important to note that any given level of benzene in a household air sample that falls within this typical background level for indoor air in the United States does not necessarily indicate that the benzene is entirely from an indoor (non site-related) source. Because benzene is considered a site-related contaminant of concern, all exposures above typical background levels may be related to the site; therefore, ATSDR considers exposures to concentrations of benzene above 6 $\mu g/m^3$ to result in a completed exposure pathway.

Public Health Implications

Benzene: Chronic Exposure and Non-Cancer Health Effects

To evaluate non-carcinogenic health effects, ATSDR has developed Minimal Risk Levels (MRLs) for contaminants that are commonly found at hazardous waste sites. An MRL is an estimate of a level of daily human exposure to a contaminant. When exposure levels are below the MRL, non-cancerous adverse health effects are unlikely. MRLs are developed for each route of exposure (*e.g.*, ingestion and inhalation), and for the length of exposure (*i.e.*, acute, less than 14 days; intermediate, 15–364 days; and chronic, 365 days or more). Because ATSDR has no methodology to determine amounts of chemicals absorbed through the skin, there are no MRLs for skin exposure. ATSDR presents information on MRLs in its series of Toxicological Profiles on hazardous substances. These chemical-specific profiles provide information on health effects, environmental transport, human exposure, and regulatory status. If a chronic MRL has not been developed for a contaminant, the EPA RfD or the RfC are used if available. The RfD is an estimate of the daily exposure of a human population through ingestion of a potential hazard that is unlikely to cause carcinogenic adverse health effects during a person's lifetime. The definition for a RfC is the same except that an RfC is for inhalation rather than ingestion.

Most of the levels of benzene that have been found in the homes and buildings in La Salle were below ATSDR's intermediate MRL of 13 $\mu g/m^3$ for less serious neurological effects that were found in a study of mice (Li et al., 1992). The maximum level of benzene that has been detected is about 100 times below the less serious neurological effect seen by Li et al., which may not cause adverse health effects at all. None of the benzene levels were above ATSDR's acute MRL. Therefore, at the maximum benzene level that was detected, exposures with a duration of one day to one year are not likely to result in adverse health effects. ATSDR has not developed a MRL for chronic exposure duration; however, the EPA RfC for benzene is available. The measured indoor concentrations of benzene found in the homes and buildings in LaSalle were below the EPA chronic RfC of 30 $\mu g/m^3$. The cancer effects for benzene are discussed below.

Benzene: Chronic Exposure and Cancer

In general, benzene causes adverse effects on blood. People who breathe high levels of benzene for long periods of time are likely to have reduced red blood cell production (*i.e.*, anemia). Studies of people who have worked with or around benzene have consistently linked benzene exposures with a particular type of leukemia. Results of animal studies have shown that benzene causes cancer in animals (ATSDR, 1997). The primary end point of concern for benzene air