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Risk of leukemia as a result of community exposure to gasoline vapors: A follow-up study

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ABSTRACT

Objectives: To assess the temporal and spatial relationship of risk for total leukemia and AML (acute myelogenous leukemia) among community residents of an area in northeastern (NE) Pennsylvania (PA) affected by the Tranguch Gasoline Spill which occurred in the early 1990s.
Methods: Standardized incidence ratios (SIR) were calculated for total leukemia and AML among 625 residents affected by the gasoline spill in relation to both PA and local county cancer incidence rates. The risk of total leukemia and AML among the gasoline exposed population was evaluated for the period prior to the spill, 1985–1989; during the time surrounding the spill, 1990–1994; and for a period subsequent to the spill, 1995–2001.
Results: The incidence of total leukemia and AML was significantly elevated subsequent to the spill for the entire period 1990–2001 and was highest for the period 1995–2001, whether comparison was made to PA or local county leukemia rates. Based on comparison to PA rates, the SIRs for total leukemia and AML were 7.69 (95% CI=1.58–22.46) and 11.54 (95% CI=2.38–33.69) for the 1995–2001 period, respectively. Prior to the spill, 1985–1989, and during the period of the spill, 1990–1994, no cases of leukemia were identified among the affected residents.
Conclusions: These results suggest a possible association between chronic low level benzene exposure and increased risk of leukemia among residents of the Tranguch Spill Site in NE PA. Our study provides additional support to the growing body of evidence implicating low level benzene exposure and cancer risk. We recommend that other communities contaminated with gasoline vapor through leaking underground storage vessels be monitored for elevated risk of leukemia.
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1. Introduction

In 2001, the local governments of Hazle Township and the City of Hazleton, in Luzerne County in northeastern (NE) Pennsylvania (PA), sought the assistance of the University of Pittsburgh Graduate School of Public Health (GSPH) due to health concerns related to a leaking underground storage tank. The Pennsylvania Department of Environmental Protection (PADEP) documented that as early as 1993 a large quantity of gasoline began leaking from rusting underground storage tanks at a site previously identified as the Tranguch Tire Resurfacing and Gasoline Station (Patel et al., 2004). The exposures occurred as a result of gasoline contaminating the groundwater and filtering into the sanitary sewer system. As the gasoline vapor migrated through the sewer system, some residents complained about smelling vapors in their homes. The chronic exposure to low levels of benzene and other petroleum distillates raised the concern of the residents about potential health effects. A retrospective cohort study was conducted to determine if there was an increased cancer risk in this population (Patel et al., 2004).

During the study period, the average benzene content of gasoline in the United States (US) was estimated to have ranged between 1% and 2% by volume (Krewski et al., 2000). Because of the benzene content, an *a priori* concern from exposure to gasoline among the community residents was whether or not an elevated incidence of leukemia might be observed. This concern was based on studies demonstrating elevated risks of leukemia and other manifestations of bone marrow toxicity from exposure to either benzene or gasoline. In some of the earlier occupational cohort studies, leukemia risk had been associated with high level benzene exposure (100–200 ppm or greater) (Aksoy et al., 1974;

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Aksoy and Erdem, 1978; Vigliani and Saita, 1964; Vigliani, 1976; Infante, 1993; Rinsky et al., 1987). Other community-exposure studies have also demonstrated elevated leukemia risks, including acute myelogenous leukemia (AML), as a result of low level and low cumulative benzene exposures (Bond et al., 1986; Hayes et al., 1997; Hayes et al., 2001; Guenel et al., 2002; Glass et al., 2003; Collins et al., 2003; Kirkeleit et al., 2008).

Workers exposed to benzene have demonstrated significantly reduced blood cell counts and depression of myeloid progenitor cell colony formation as a result of exposure levels of less than 1 ppm (Qu et al., 2002; Lan et al., 2004; Lan et al., 2006), indicating immunosuppression. Some epidemiological studies of those dispensing gasoline have demonstrated significantly elevated risks of leukemia and other blood diseases (Schwartz, 1987; Jakobsson et al., 1993; Terry et al., 2005 Lumley et al., 1990; Naizi and Fleming, 1989), as well as chromosomal damage to blood lymphocytes (Oesch et al., 1995; Hogstedt et al., 1991). In one study (Terry et al., 2005), the data demonstrate a significant increase in the risk of AML for those employed as a gas station attendant for more than a year; OR=1.8 (95% CI=1.1–2.9). However, a large study of gasoline attendants from the Nordic countries did not observe an overall statistically significant elevated risk of AML (Lynge et al., 1997); the SIR was 1.4 (95% CI 0.8–2.4).

The evaluation of relative risk for Patel et al's. (2004) study was conducted for 10 separate cancer sites for the 11-year period of follow-up (1990–2000) and results indicated that total leukemia (ICD-9, 204–208) was significantly elevated compared to Pennsylvania and Luzerne County, PA, cancer incidence rates by age and gender. Standardized Incidence Ratio (SIR)=4.4 (95% CI=1.09–10.24) (Patel et al., 2004; SEER, 2011). There were 43 reported and verified total cancers in this population with 49.1 expected compared to the state of PA, yielding an SIR of .88 (95% CI: 0.64–1.18). No other SIRs for cancer sites were significantly elevated.

In this phase of our study, we: (1) present data for an additional year of follow-up; (2) consider temporal and spatial relationships between exposure to the gasoline spill and risk of leukemia; and (3) report on AML risk known to be more closely related with benzene exposure.

2. Materials and methods

2.1. Benzene exposure estimates

Prior to the Environmental Protection Agency's (EPA) remediation efforts which began in 1996, the PADEP tested the indoor air of a subset of homes for the concentration of total volatile organic compounds (VOCs). A Hnu photo ionization detector (PID) (ATSDR, 2004) was used to obtain samples from 43 homes over the course of 72 days (49 sampling days). Total VOCs concentration ranged from 0–202 ppm with an estimated benzene concentration range of 0–42 ppm (0–136 mg/m^3). Benzene levels in the groundwater of the Tranguch Spill area were estimated by the EPA and The U.S. Army Corps of Engineers through exposure modeling conducted between 1994 and 1996. Groundwater estimates of benzene ranged from 200 to 2500 μg/m^3 (23). The "affected" area consisting of 366 households within the Hazle Township and the City of Hazleton municipalities potentially exposed to gasoline fumes as a result of the Tranguch fuel spill was determined by the EPA. Using these surveys and taking into consideration possible vapor migration through the sanitary sewer system, the EPA defined a remediation area (Fig. 1) (PADoH, 2001).

Although the EPA sampled the affected residential properties for concentrations of indoor benzene using Summa canisters in late 2000 and January 2001, cumulative benzene exposure could not be adequately estimated due to the lack of comprehensive historical data on air and groundwater concentrations and duration of exposure. Approximately 20% of home owners provided their results to investigators. The reported levels of household benzene exposure ranged from non-detectable (<8.3 μg/m^3) to 140 μg/m^3. As a result, exposure to benzene from the leaking tanks was defined by residence within the EPA defined remediation area (ATSDR, 2004).

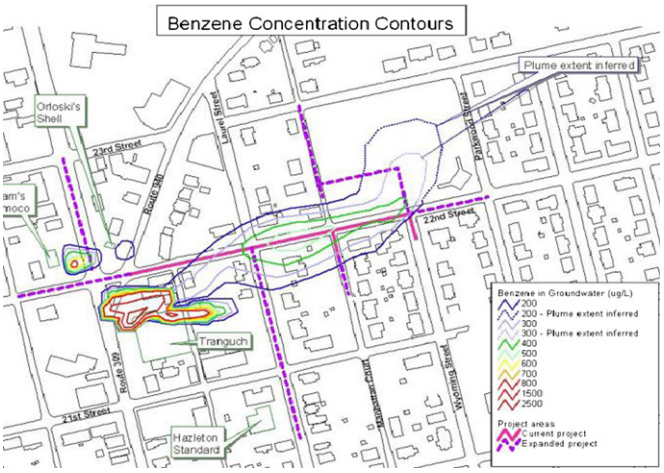

Fig. 1. Benzene Concentration Contours in the Gasoline Plume. (EPA and US Army Corps of Engineers (1998)).

2.2. Details of the study design and target population

Details of the study design, target population, and data collection for the study were provided in the previous publication (Patel et al., 2004). The EPA designated 366 properties in Hazle Township and the City of Hazleton as potentially affected by the spill and 347 of these were determined to be residential. This then comprised our study area.

The original cohort was constructed from tax records, municipal lists, and residential histories of persons living for at least 6 months within the EPA remediation ("affected") area between January 1, 1990 and December 31, 2000. A study-specific questionnaire was developed to assess demographics and primary and secondary health outcomes. The questionnaire obtained self-reported information on residential, medical, and occupational history, health habits, and lifestyle factors. Six consent-to-participate forms, 3 study questionnaires, and 3 medical record release forms were mailed to each current and former head of household and were included for all family members of the affected properties to inform them of the study. A combination of telephone interviews and in-person interviews were also carried out to improve the response rate. Data was collected in the summer of 2001 for the smaller population of Hazle Township, PA and during the summer of 2002 for the City of Hazelton, PA.

Incident cases of cancer among residents of the Hazle Township/City of Hazleton affected area from 1990 through 2001 were identified via the questionnaires. For all self-reported cancers, a request was made by a study staff member for the release of the medical records to the investigators and verification by the attending physician of cancer diagnosis, cancer site, and disease status. A request was also made to the PA Department of Health (PADoH) for the confirmation of all self-reported cancers using data from the PA Cancer Registry as well as validation of any additional non-reported cancers for all study participants. For purposes of this follow-up study, we have added the 2001 cancer data not used in the previous analyses due to lagged PA Cancer Registry information.

As part of this University of Pittsburgh study, no formal medical visits to detect aplastic anemia or leukemia among exposed residents were conducted. The PADoH, however, provided free complete blood tests (CBCs) beginning in 2001 for all residents in the study area in collaboration with St. Joseph's Hospital in the City of Hazleton as a result of the heightened awareness concerning the gasoline spill. A total of 400 individuals underwent this test. Results of the test were sent directly to family physicians. We know of no cases of leukemia identified in this fashion (PADoH, 2001).

2.3. Statistical analyses

The present analysis focused on total leukemia, specifically AML as these cancers have been linked to benzene exposure. An indirect method was used to calculate standardized incidence ratios (SIRs) and 95% confidence intervals (CIs) for total leukemia, including acute lymphoblastic leukemia (ALL, ICD-9 code: 204.0), chronic lymphocytic leukemia (CLL, ICD-9 code: 204.1), acute myelogenous leukemia (AML, ICD-9 code: 205.0), and chronic myelogenous leukemia (CML, ICD-9 code: 205.1) (SEER, 2011; Gordis, 2008). Since cancer is a rare event, Poisson distribution tables (Breslow and Day, 1987) were used to determine the 95% confidence intervals. Due to the small number of observed cases for site-specific outcomes, exact methods were used.

The observed number of cancers in the exposed areas of Hazle Township and the City of Hazleton were compared to expected numbers derived from age and

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