Examining Potential Relationships between Cancer Incidence and Ground Water Contamination with Trichloroethylene (TCE) and Tetrachloroethylene (PCE) in Lisle and Downers Grove, DuPage County, Illinois

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ABSTRACT

BACKGROUND: From late 2000 to early 2002, more than 900 private wells in Lisle and Downers Grove, DuPage County, Illinois were sampled and tested for chemical contaminations, and trichloroethylene (TCE), tetrachloroethylene (PCE) or both were detected in many of the sampled wells. Concerns about cancer occurrence in the area prompted the present study examining relationships between the environmental hazard data and cancer surveillance data.

OBJECTIVES: Examined cancer incidence relative to different levels of TCE/PCE in private wells.

METHODS: The Illinois State Cancer Registry's cancer incidence database and the Illinois Environmental Protection Agency's (IEPA) Lisle and Downer's Grove Ground Water Investigation Database were two data sources for the analysis. Age-adjusted cancer incidence rates in the concerned area were calculated and compared with those in entire DuPage County. Cancer incidences were linked with TCE/PCE contamination at both census tract and residential address levels, and the possible association between them was evaluated.

RESULTS AND CONCLUSIONS: Based on the information currently available for the study, no significant elevation of cancer incidence was found in the target area, and no correlation was suggested between TCE/PCE contamination in well water and increase of cancer incidence.

BACKGROUND

Lisle and Downers Grove are neighboring communities in DuPage County, Illinois. In late 2000, a group of residents in Lisle became aware of an on-site contamination situation at the nearby Lockformer facility, uphill from their houses. They arranged through an attorney for the sampling of their private wells. When a number of the wells showed Trichloroethylene (TCE) contamination, the data were shared with the Illinois Environmental Protection Agency (IEPA). More private wells were then sampled and tested for contamination by IEPA. TCE was detected in many of the sampled wells with the highest level being 19.5 micrograms per liter water (µg/L). The U.S. Environmental Protection Agency's (USEPA) drinking water standard or maximum contaminant level (MCL) for TCE in public water supplies is 5 µg/L.[1] With the findings in Lisle and based on earlier volatile organic compound (VOC) contamination that led to the closing of two community water supply wells in a Downers Grove neighborhood, beginning in May 2001, a large number of private wells in Downers Grove were also tested for contamination. TCE, tetrachloroethylene (PCE), or both were found in some wells. The highest levels of TCE and PCE detected were 16.6 µg/L and 12.1 µg/L, respectively. The highest combined level of TCE and PCE was 18.6 µg/L. At the request of the IEPA, the Illinois Department of Public Health (IDPH) conducted public health assessments in each community and indicated that exposure to the levels of TCE and PCE found in these two communities would pose a very low increased risk of adverse health effects.[2,3]

TCE is used mainly as a degreaser for industrial metal parts and PCE is used for dry cleaning, metal cleaning, and chemical intermediates. According to the report on carcinogens published by the National Toxicology Program, both TCE and PCE are classified as *reasonably anticipated to be human carcinogens.*[4] Possible links between exposure to the chemicals and excess cancer rates of liver, kidney, lymphoma, myeloma, prostate, and cervix have been suggested based on previous studies, with stronger evidence for the first three cancers.[5] Humans can be exposed to TCE and PCE through occupational exposure or simply by drinking contaminated water or inhaling contaminated air.[6]

There has been considerable public concern about cancer in Lisle and Downers Grove, and the concern became even more intense after residents were notified of the water sampling results. Therefore, the objectives of this project included: 1) addressing the community concerns by evaluating whether elevated cancer incidence rates existed in the area, and 2) establishing a long-term model for linking and reporting environmental and health effect data to inform the public and to improve public health.

METHODS

Cancer cases and population

Cancer incidence data were from the Illinois State Cancer Registry (ISCR), the only source of population-based cancer incidence data for the state. ISCR collects cancer cases through mandated reporting by hospitals, ambulatory surgical treatment centers, and non-hospital affiliated radiation therapy treatment centers, and through the voluntary exchange of cancer patient data with other central registries. ISCR has high quality cancer incidence data in terms of completeness, accuracy, and timeliness of reporting,[7] as attested by its annual gold certification from the North American Association of Central Cancer Registries (NAACCR) since 1997.

For this study, all invasive cancer cases diagnosed from 1998 through 2002, with the exception of bladder *in situ*, among the DuPage County residents were selected for the analysis. The case information including year of diagnosis, sex, race, age at diagnosis, home address at diagnosis, primary site, histology, behavior, etc., were obtained from the cancer database (data as of November 2004).

Population counts used for the calculation of cancer incidence rates were derived based on the 2000 U.S. Census. Sex-age specific population counts for each census tract in DuPage County were obtained from the Web site of 2000 Census.[8] The five-year (1998 – 2002) population count for each corresponding sex-age group was derived by multiplying the 2000 census count by five.

Well water samples

The data source for well water samples was from the IEPA's Lisle and Downers Grove Ground Water Investigation Database. The well samples in this database were collected from late 2000 to early 2002 in the neighboring communities of Lisle and Downers Grove. The database contained the information of sampling date, home address of well location, TCE and PCE testing results, and well owner's name.

Geocoding

Using the address information in the two databases, both cancer cases and well samples were geocoded using MapInfo® MapMarker® Plus software (version 9.0). Geocoding resulted in the assignments of longitude, latitude, and census tract information to each record. However, if records had invalid or incomplete addresses, the geocoding results were left blank.

Statistical analysis

Prediction of TCE/PCE contamination. Based on the longitude and latitude assigned from geocoding, well samples were mapped. TCE and PCE contamination levels were known only for these sampled locations. In order to produce a continuous TCE and PCE contamination map for the area, the Kriging technique[9,10], one of spatial prediction methods, was used to make the prediction. Due to the limited prior knowledge about which model would best describe TCE and PCE distribution for the ground water, various model options that were available in the geostatistical analyst (one of ArcGIS® extensions) (version 9.0) were explored with different parameter settings. The final model was selected based upon cross validation test results. Since the ordinary Kriging with spherical function had the smallest root-mean-square value in the cross validation tests, this model was used to predict the TCE and PCE contaminations. In this study, the combination of TCE and PCE (TCE/PCE) was considered to maximize the risk.

Cancer incidence rate. Annual age-adjusted cancer incidence rates were calculated for each of 147 census tracts in DuPage County, using Seer*Stat software (version 6.1). All cancer sites combined and six cancer sites combined (cancers of liver, kidney, lymphoma, myeloma, prostate, and cervix, which were possibly linked to TCE/PCE exposure based on literature) were considered. The 95 percentage confidence intervals for rates were also calculated as rough estimates of statistical significance for rate comparisons. In addition, standardized incidence ratios (SIR) were calculated for each census tract with cancer incidence rates for DuPage County as a reference.

Correlation between cancer incidence rate and level of TCE/PCE contamination. Pearson correlation coefficients between cancer incidence rate – all sites combined and six sites combined, and TCE/PCE contamination level were calculated in several combinations. From the aspect of cancer incidence rate, both directly and indirectly age-adjusted rates were used for the evaluation; from the aspect of TCE/PCE contamination level, both the measured (based on the well samples) and predicted (based on the Kriging method) mean TCE/PCE values were used for the evaluation.

Linkage between cancer database and well database based on street address. Due to the fact that not all residents in the area had private wells and some of them were on public water supply, a more precise way to evaluate the association between level of TCE/PCE contamination and cancer incidence should be based on only the residences that had private wells. To do this, a linkage between cancer cases and well samples was performed through the standardized street address; a two by two table was then constructed based on the level of TCE/PCE concentration (>MCL or <MCL) and presence/absence of cancer cases on specific street addresses with private wells. A chi-square statistic was calculated for statistical significance testing.

Detection of spatial cancer cluster. Kulldorff's spatial scan test[11,12] was used to detect if there was any significant spatial cancer cluster in DuPage County and, if so, where the clusters were located. During the evaluation, covariate adjustments were done for both age and sex. All cancer sites combined and six cancer sites combined were considered.

RESULTS

A total of 19,093 invasive cancer cases, with the exception of bladder *in situ*, were accessioned from the Illinois State Cancer Registry database. All these cases were diagnosed during 1998 to 2002 and were residents of DuPage County, Illinois. After geocoding, 96.2 percent of these cases were appropriately assigned to 2000 census tract codes and 92.6 percent were assigned longitude and latitude coordinates at street level.

More than 900 well samples were contained in the IEPA's Lisle and Downers Grove Ground Water Investigation Database. About 24 percent of these samples had combined TCE/PCE levels above the federal drinking water standard with a range of 0 to 20 µg/L. Census tract level geocoding was achieved for 99.4 percent of the well samples while street level geocoding reached 97.9 percent.

Figure 1. Map of DuPage County census tracts, residential well sample locations, and predicted TCE/PCE contamination

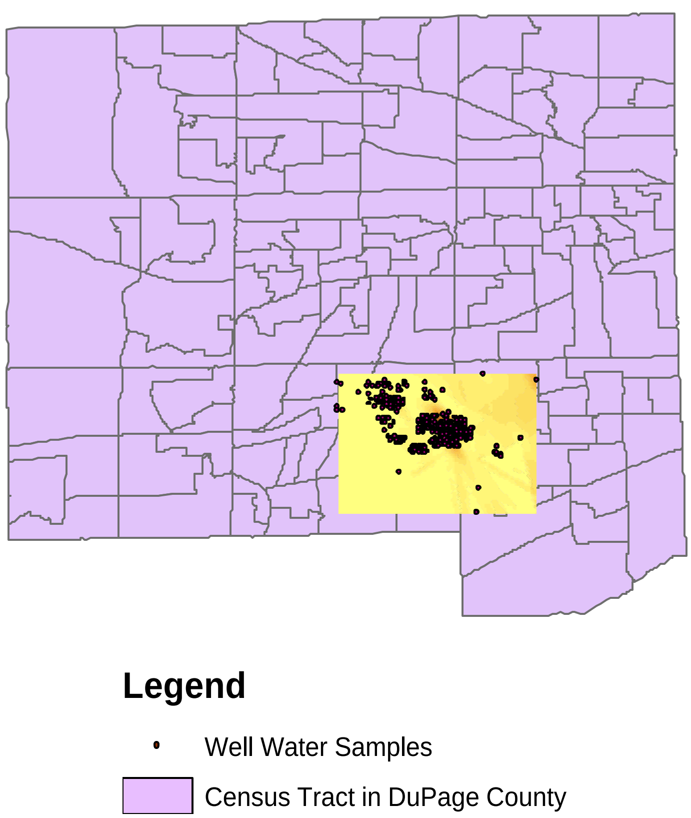


Figure 1 shows DuPage County census tracts, locations of sampled residential wells and predicted TCE/PCE contaminations. An enlarged TCE/PCE contamination prediction map is also shown in Figure 2. The level of contamination is indicated by color with the light yellow having the lowest level of TCE/PCE and dark brown having the highest level of TCE/PCE (see the legend). The geographic extent of the prediction covered 20 census tracts (844800, 844900, 845503, 845601, 845602, 845701, 845702, 845703, 845704, 845801, 845802, 846001, 846002, 846104, 846301, 846302, 846304, 846305, 846306, 846307), with each of these tracts either having sampled wells or having predicted TCE/PCE values. These 20 census tracts surround the suspected TCE/PCE contamination sources. In this study, these 20 census tracts were defined as a target area for evaluation (Figure 3), and entire DuPage County was used as a comparison area.

Figure 2. Enlarged contamination prediction map for TCE/PCE

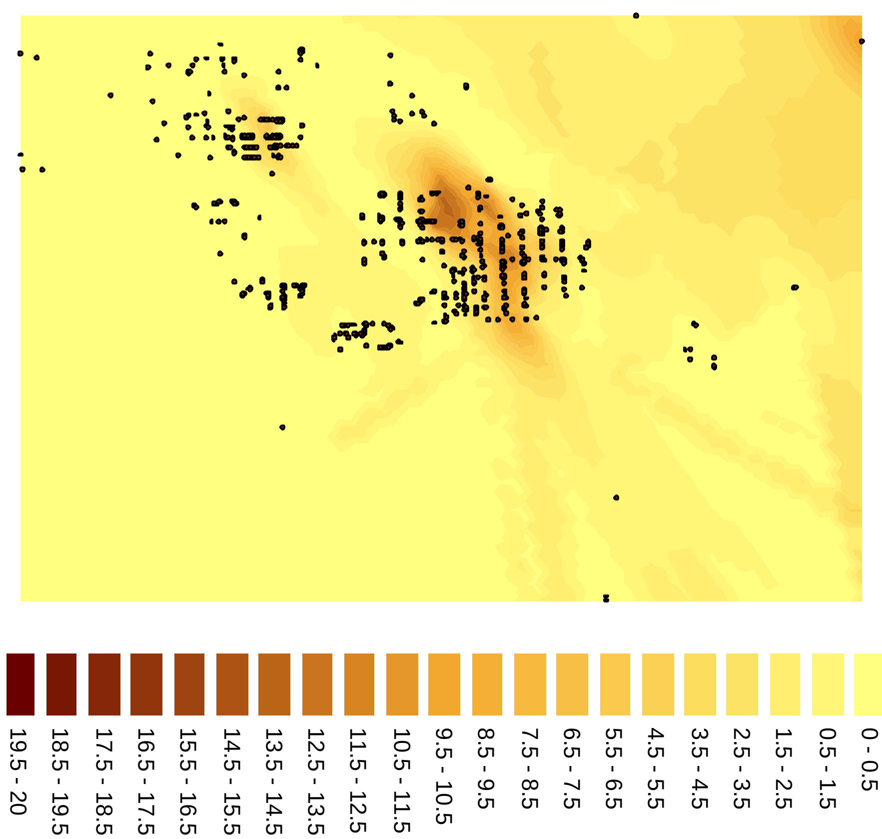
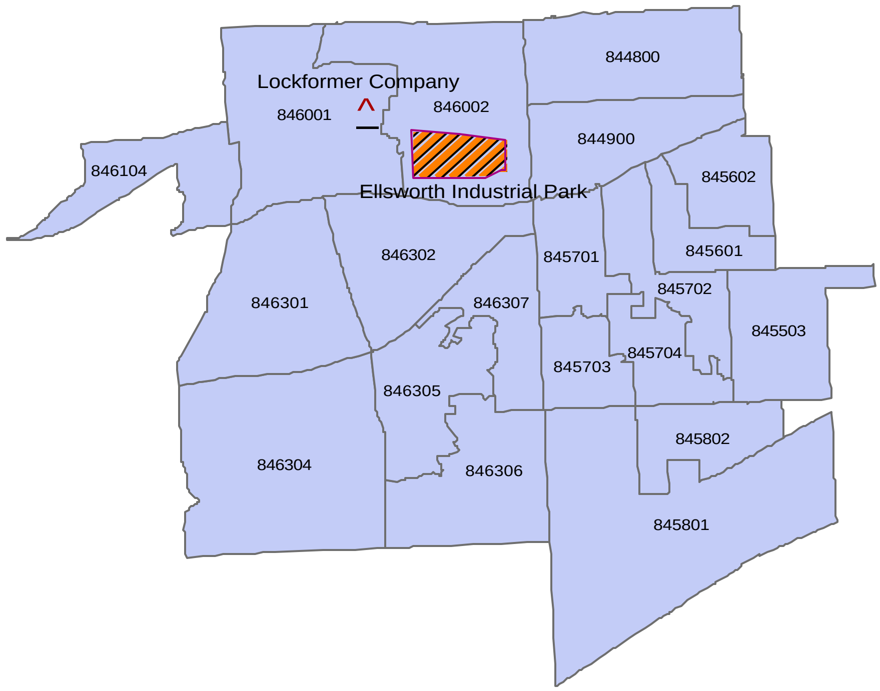


Figure 3. Map of target area – 20 census tracts



Annual age-adjusted cancer incidence rates for all cancer sites combined and six cancer sites combined in the target area and DuPage County are given in Table 1. With all cancer sites combined, cancer incidence rate in the target area was slightly higher than that in DuPage County; however, since 95 percent confidence intervals for the rates were largely overlapped, the differences were not statistically significant. On the other hand, with only the six cancer sites combined, the cancer incidence rate for the DuPage County was slightly higher than that in the target area; once again, statistically this difference was not significant due to overlapping confidence intervals.

Table 1. Age-adjusted cancer incidence rates for the target area and DuPage County

Cancer Site	Target Area (20 Census Tracts)		All DuPage Census Tracts Combined	
	Incidence Rate*	95% Confidence Interval	Incidence Rate*	95% Confidence Interval
All Cancer Sites Combined	471.3	453.6 – 489.4	466.7	459.9 – 473.6
Six Cancer Sites Combined#	116.6	107.8 – 125.9	118.3	114.9 – 121.9

*Rates are per 100,000 and are age-adjusted to 2000 US standard million population.
Include cancers of liver, kidney, lymphoma, prostate, cervix, and myeloma.

Table 2 shows Pearson's correlation coefficient between cancer incidence rates (directly or indirectly age-adjusted) and TCE/PCE contamination (measured or predicted). All associated P values were greater than 0.05 (a level), and these suggested that there were no significant correlations found between cancer incidence and contamination of TCE/PCE in ground water.

Table 2. Correlation between cancer incidence rate and TCE/PCE contamination in ground water

	Cancer Site	Measured TCE/PCE		Predicted TCE/PCE	
		Pearson's Correlation Coefficient	P Value	Pearson's Correlation Coefficient	P Value
Directly Age-adjusted Cancer Rate	**All Cancer Sites Combined**	0.130	0.67	-0.019	0.94
	Six Cancer Sites Combined	0.383	0.20	-0.310	0.18
Indirectly Age-adjusted Cancer Rate	**All Cancer Sites Combined**	0.183	0.55	0.018	0.94
	Six Cancer Sites Combined	0.48	0.10	-0.206	0.38

When linking the cancer data with the well data based on the standardized street address, 53 matches were found. Among the 53 matched well samples, 13 wells (24.5%) contained TCE/PCE higher than the federal drinking water standard. The mean TCE/PCE level was 2.96, which was slightly higher than the mean value of 2.82 for the unmatched well samples, but the difference was not statistically significant based on Wilcoxon two sample test (statistic = 26385, p value = 0.51). For the 53 matched cancer cases, 12 cases (22.6%) were among the cancer sites of liver, kidney, lymphoma, myeloma, prostate, or cervix, and this percentage distribution was similar to that in DuPage County (23.9%). To further evaluate the association between the TCE/PCE concentrations of well samples (< MCL or = MCL) and likelihood of cancer case diagnosis, a 2x2 contingency table was set up based on the cross-classification (Table 3) and a Chi-square statistic was calculated. Since the continuity adjusted Chi-square value was close to zero and associated P value was about one, this suggested that there was no significant association between level of TCE/PCE contamination and cancer case diagnosis.

Table 3. Association between TCE/PCE concentrations of well samples and likelihood of cancer case diagnosis#

		Cancer Case Diagnosis		
		Yes	**No**	**Total**
Level of	**= MCL***	13	206	**219**
TCE/PCE in	**< MCL**	40	657	**697**
Well Samples	**Total**	**53**	**863**	**916**

* MCL: maximum contaminant level. The MCL for TCE/PCE in public water supplies is 5 µg/L.
# Continuity adjusted ?^{2} = 0, P value = 1

When the Kulldorff's spatial scan test was run for both all cancers sties combined and six cancer sites combined on DuPage County census tracts, no significant cluster was detected in the target area.

DISCUSSION

In this study, cancer incidences diagnosed from 1998 – 2002 in two neighborhood communities of Lisle and Downers Grove, DuPage County, Illinois, have been examined for all cancer sites combined and six cancer sites combined. The reason for selecting these six specific cancers (liver, kidney, lymphoma, myeloma, prostate, and cervix) for evaluation was because some studies have suggested possible links between occurrence of these cancers and exposure to TCE/PCE. Due to small number of cases in census tracts, the evaluation has not been performed for individual cancer sites.

Based on the current study, the cancer incidence rates in the target area (20 census tracts surrounding the suspected contamination sources) were similar to those in DuPage County, and no significant elevation of cancer incidence was found in the area. When linking the cancer incidence rate with the TCE/PCE contamination for each census tract, no significant correlation was found either.

Linkage between environmental data (IEPA's Lisle and Downers Grove Ground Water Investigation Database) and cancer incidence data (Illinois State Cancer Registry Database) was also performed based on residential address. For the matched well samples, the level and distribution of TCE/PCE contamination were similar to those for all wells tested. For the matched cancer cases, the distribution of cancer sites was similar to that when all cancer cases were considered. These suggested that the locations where there were cancer cases diagnosed during the time period studied did not appear to have higher TCE/PCE contamination, and also no increased number of diagnosed cases were among six TCE/PCE exposure linkable cancer sites.

Both TCE and PCE are *reasonably anticipated human carcinogens*.[4] The potential for exposed persons to experience adverse health effects depends on many factors, such as the concentration of TCE/PCE present, the length of time a person is exposed, and the health condition of the person exposed.[2, 3] Many previous studies[13-15], in which possible associations between exposure to TCE/PCE and occurrence of certain types of cancers were suggested have been based on occupational exposure. Occupational exposures usually tend to have higher concentration of chemicals and longer exposure time. In this study, the level of TCE/PCE contamination in residential wells ranged from 0 to 20 µg/L, which was also relatively lower than the contamination detected in other studies.[16, 17] In addition, some important information regarding residential history, water use or consumption history, and any pre-existing health conditions was lacking in this study. Failing to take this information into account in the evaluation might have an effect on the results.

Before drawing any conclusions, the following aspects regarding the study also need to be considered. First, cancer incidence rates calculated for some census tracts might not be stable. In this study, cancer incidence rates were calculated in census tract level based on five-year aggregated data (1998 – 2002). For census tracts that had small population sizes, the incidence rates calculated might not be reliable, especially when only certain types of cancers (e.g. six cancer sites combined) were considered. One way to solve this problem is to include more years of data in the analysis, such as using 10-

year aggregated cancer data (1991 – 2002) instead of five years. However, since sex-age-specific population counts in census tract level are not readily available from U.S. census data for individual years (except in census years, e.g. 1990, 2000), a certain algorithm has to be applied to estimate the intercensal population counts. In addition, the split and revision of some census tracts over time could complicate the population estimations.

Secondly, the accuracy of TCE/PCE contamination for each census tract should be considered. In this study, the average of TCE/PCE contamination for each census tract was estimated in two different ways: one was based on the measured TCE/PCE from the sampled wells, and one was based on the predicted TCE/PCE using the Kriging technique. Since wells were not sampled evenly among the census tracts, the accuracy of the calculated mean contamination of TCE/PCE for each census tract would vary, with the census tracts having only a few wells sampled having a less accurate mean. Consequently, the correlation measure based on them could be affected. On the other hand, when the predicted TCE/PCE was used, even though a relatively good model had been selected for the prediction, it was difficult for any mathematical model to capture all these complexities since the movement of ground water is complicated. In addition, the predicted TCE/PCE contamination for census tracts that did not contain any well samples tended to be less accurate, and inclusion of these census tracts in the evaluation might have an effect on correlation results as well.

Thirdly, the discrepancy between the estimate of TCE/PCE contamination and the true level of exposure to the chemicals for residents should be taken into account. In this study, correlation between TCE/PCE contamination level and cancer incidence rate was evaluated at the census tract level. However, we should keep in mind that TCE/PCE contamination level did not necessarily reflect the level of exposure for residents, since not all the residents in a certain census tract had private wells. Therefore, some residents, even though they lived in an area with higher estimated contamination, might not be exposed to the chemicals at all, simply because they used public water supply instead of private wells. This discrepancy certainly complicates the interpretation of correlation results. This however should not be a problem when cancer incidences were directly linked with well samples at street address level, as we also did in this study, since under this situation only the residents that had private wells were considered and residents that were on public water supply were excluded.

Fourthly, the primary epidemiological limitation in this study lies in the timing between exposure and disease. The latency between the time of exposure and the onset of a clinically-recognizable disease for most adult cancers is often between 10 to 20 years. In the current evaluation, cancer incidences used occurred at the same time or before the potential exposure was measured. If TCE/PCE contamination had occurred for a long time period and the level of contamination was stable over time, the correlation evaluated in this study between cancer incidence rate and TCE/PCE contamination would be meaningful. However, if these assumptions were not met, the correlation results should be interpreted with caution. To address this limitation, additional data collection would be needed, including information such as when the contamination roughly started, how long and how many people have been living at the current address, how much contaminated water has been used daily by each resident, and how it was used.

Finally, ungeocoded cancer cases and well samples might have influenced the results. In this study, statistical analysis was performed based on the cases and well samples that have been successfully geocoded to census tract or street address, and ungeocoded cases or well samples have been ignored. The effect of ungeocoded well samples was expected to be very small since only a few samples were not geocoded. However, the ungeocoded cancer cases might affect the results if they were not randomly distributed among census tracts. Cancer incidence rates for the census tracts with lower geocoding rate would be underestimated more. The small geographic scale analysis of the census tract level was heavily dependent on geocoding rates; therefore, having valid and accurate address for each case or record is very important.

Despite of limitations mentioned above, the present study has demonstrated several ways to link environmental and health effect data for public health evaluation, and lessons learned from this endeavor certainly can help design better future studies. As we prepared this report, we learned that all private wells in the concerned area have been replaced by public water supply, and residents will no longer be exposed to TCE/PCE by contaminated private wells.

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