Health Consultation

Exposure Investigation Report

PENNTEX RESOURCES, ILLINOIS/LAWRENCE OIL FIELD

GREATER BRIDGEPORT AREA

LAWRENCE COUNTY, ILLINOIS

MARCH 20, 2008

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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Prepared by:

U.S. Department of Health and Human Services
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TABLE OF CONTENTS

Objective

The Agency for Toxic Substances and Disease Registry (ATSDR) conducted this Exposure Investigation (EI) to determine if levels of hydrogen sulfide in indoor or outdoor air are present at levels of health concern in the greater Bridgeport, Illinois community. Indoor and outdoor air were continuously sampled and analyzed for a four week period in June and July 2006 at six area locations.

1.0 Background and Statement of Issues

PennTex Resources Illinois Inc. (PennTex) operates an oil field located within and surrounding the small city of Bridgeport, Illinois. PennTex operates four crude oil fields (three in Illinois and one in Indiana). The largest is the Lawrence Field in Lawrence County, Illinois (ATSDR, 2006a). The Lawrence Field has approximately 1,300 production wells and 700 injection wells, and produces an average 150,000 barrels of oil each year. Bridgeport is located within the boundaries of the Field. The Field has been operating for 100 years (Rex Energy Corp., 2006). PennTex has been owned by a number of companies since it was established in 1906. Rex Energy purchased the Field in January, 2005 (meeting with Rex Energy, Sept 7th, 2006).

Twenty gas wells are located within Bridgeport city limits. Residents feel that some of these have been historically problematic. Emissions from other wells immediately outside the city limits, particularly in Petrolia, have also resulted in a number of complaints. PennTex utilizes several different air pollution controls within the Lawrence Field, including flares, H_2S Scavenger Drums, and Sulfa-Treat Drums (ATSDR, 2006b).

In December 2005, the Agency for Toxic Substances and Disease Registry (ATSDR) was requested by the United States Environmental Protection Agency (U.S. EPA), Region 5 Air and Radiation Division to evaluate health concerns of residents living near oil wells in the Plains Lawrence Field. The site had come to U.S. EPA's attention through citizen complaints. In late December 2005, U.S. EPA provided ATSDR with a packet of information including: citizen complaint logs from Illinois Department of Natural Resources (IDNR); a PennTex funded odor report; and correspondence between residents, Illinois EPA, U.S. EPA, IDNR, the mayor of Bridgeport, and state and federal Congressmen. On January 27, 2006, ATSDR Region 5 and the Illinois Department of Public Health (IDPH) issued a consultation memo to Mr. Steve Rothblatt, the Director of U.S. EPA's Division of Air and Radiation. The conclusion listed in the consultation memo was that current conditions could pose a public health hazard to residents of Bridgeport and that steps should be taken to characterize the exposures and mitigate them, if warranted (ATSDR, 2006b). ATSDR has since participated in a number of meetings with U.S. EPA Air Division Staff to discuss an appropriate response to issues in Bridgeport.

Given the potential for significant exposures and the lack of data, ATSDR and U.S. EPA conducted air sampling in the community. ATSDR sampled in six locations, three of which were residential. U.S. EPA also sampled at three residential locations, two of which were different than those ATSDR sampled. This document will evaluate the results from the ATSDR Exposure Investigation (EI) and the U.S. EPA air investigation conducted in summer 2006.

1.1 *Community Health Concerns and Available Data*

The issues cited in the IDNR complaint report logs that were reviewed by ATSDR included reports of significant odors emanating from the oil wells. These odor complaints appear to coincide with conditions where the air is still, and when either the gas flares are not operating or when the well gas treatment systems are inadequate to absorb the released gases. As a result, excessive emissions of hydrogen sulfide gas migrate into nearby residential areas. The IDNR complaint logs contain numerous descriptions of health impacts residents believe are related to gas odors. IDNR staff has detected field concentrations up to 2000 ppm at the flare line.

At an April 2006 community meeting, ATSDR spoke with a number of residents, noting their health concerns. These health concerns include headaches, nausea, vomiting, grogginess, watering eyes, insomnia, fainting, difficulty breathing, sinus problems, allergies, and seizures. One family reported cancer and autoimmune disease, which they believe could have been caused by environmental exposures.

Also, many residents reported rusting of metal appliances and components, and metal trim on houses and cars.

1.2 *Demographics*

Bridgeport is a small city of approximately 2,200 people in southeastern Illinois, near the Indiana border. It is located in Lawrence County, a fairly rural county of approximately 15,000 people. Most of the population of Bridgeport are white (98.4%), married (51.3%), have at least a high school diploma (76.4%), and own their homes (75.9%). The majority of the homes in the area are older than 1959 (54.3%). The age distribution is fairly normal, with approximately 28.4% less than 19 years old and 18.4% older than 65 years. In 1999, 11.3% of the population lived below the poverty line, and 32% had an income of between $10,000 and $25,000 a year (U.S. Census Bureau, 2000). See Appendix A for demographic maps of the area.

1.3 *Air Monitoring*

ATSDR and U.S. EPA were interested in characterizing the range of exposures in the Bridgeport area. Therefore, it was important to obtain continuous data to identify the trends and magnitude of exposure. Environmental data presented in this document were collected through two separate efforts. ATSDR conducted an outdoor air “exposure investigation” (EI), the aim of which is to characterize community exposures to hydrogen sulfide. U.S. EPA also conducted air sampling in the community during and after the ATSDR EI. Between both agencies, air sampling was conducted at eight locations in Bridgeport and Petrolia, ranging from areas that are unimpacted by oil industry activities and areas that represent typical exposures of residents living near oil wells or collection centers to areas where the close proximity of the home to the oil facility and low-lying ground surface contribute to higher levels of exposure. See Appendix B for a map of the air monitoring locations.

2.0 ATSDR Exposure Investigation

An exposure investigation (EI) is an approach ATSDR uses to develop a better characterization of past, current and possible future human exposures to hazardous substances in the environment. There are three main ways ATSDR gathers information in an exposure investigation: bio-medical testing (for example, blood or urine sampling); environmental testing (for contaminated soil, air or water); and exposure-dose reconstruction (using environmental data and computer models to estimate past exposures). The results of exposure investigations are used to make public health decisions and to recommend appropriate public health actions.

In the Bridgeport area, there were no continuous air data available to determine whether or not levels of hydrogen sulfide were posing a health risk to residents in the community. The purpose of the EI was to collect this type of environmental data to help us better understand the magnitude, frequency, and duration of residential exposures in the community.

2.1 *Sampling locations*

The ATSDR EI focused on the outdoor and limited indoor air monitoring of hydrogen sulfide and selected volatile organic compounds (VOCs), which were measured over a 4-week period. Hydrogen sulfide and VOCs were selected for monitoring during this EI because they are commonly emitted from oil and gas facilities.

Since oil wells and collection facilities are densely distributed throughout the area, many residents are in relatively close proximity to a variety of sources of hydrogen sulfide emissions. To characterize the levels of exposure to the community, monitoring stations were located at several residences, an elementary school, and a public area. Specific locations were chosen based on their proximity to known sources of hydrogen sulfide releases, particularly oil wells, emergency pits, or oil gathering facilities. The three residential monitoring locations were selected from those volunteered by area residents, including residences in Bridgeport and nearby Petrolia. Two of these residential locations had monitoring equipment installed to sample both indoor and outdoor air. A monitoring station was placed in City Park and at the Bridgeport Grade School, both within the Bridgeport city limits. To compare the sampling results from these locations to areas that are not believed to be affected by oil field operations, a “background” location was selected at the Red Hills State Park (about 6 miles west of Bridgeport). A meteorological station was placed at the City Park location to record weather conditions during the sampling period.

2.2 *Equipment*

Hydrogen Sulfide- Zellweger Analytics Single Point Monitors (SPMs) equipped with the ChemKey® and Chemcassette® detection systems were used for monitoring hydrogen sulfide. All monitors were connected to HOBO Data Acquisition Systems™, which recorded data every 60 seconds. The detection systems have two different ranges that need to be selected at the beginning of the sampling period, either 0-90 ppb or 53 ppb-1,500 ppb (where *ppb* are parts hydrogen sulfide per billion parts air). As will be discussed later, these detection ranges can become a limitation in the analysis, since concentrations above or below these ranges cannot be quantified.

The "ChemKey" system uses a colorometric tape technology that is specific for the chemical that is being measured. The system draws in sampled air that is in contact with colorimetric tape that changes color due to a reaction of hydrogen sulfide with the reagent on the surface of the tape. The intensity of the color change correlates with the concentration of hydrogen sulfide gas in air being sampled.

Organic Compounds- Volatile organic compounds (VOCs) and non-methane organic compounds (SNMOCs) were collected according to U.S. EPA analytical method TO-15 and the U.S. EPA SNMOC analytical method. These compounds were collected in stainless steel SUMMA® canisters and analyzed for over 90 compounds in outdoor air. Samples were collected over 24 hours, in a series of three eight-hour samples. The samples of air were drawn through a calibrated flow limiting orifice assembly that regulates the rate and duration of sampling into the cleaned and pre-evacuated SUMMA® canisters. The list of target VOCs and SNMOCs, and their corresponding method detection limits (MDL) are presented in Appendix C.

Measurements of continuous meteorological parameters were made using a stand alone meteorological monitoring system. This system incorporates a cup anemometer to measure wind speed, a directional mast and vane to measure wind direction, a wound bobbin assembly to measure relative humidity, and a temperature probe to measure outdoor temperature. Measurements were made at a height of approximately 10 feet above grade (ERG, 2006).

2.3 *Monitoring*

ATSDR and its contract staff members were in the study area throughout the monitoring period. Staff visited each of the sites daily to assess the functional status of the chemical and meteorological measurement equipment and correct any problems identified. Staff downloaded data from the hydrogen sulfide monitors, reloaded chemcassettes, and performed the 2-point internal optical calibration checks weekly. Staff downloaded meteorological data weekly and performed a visual check of the meteorological sensors daily (Eastern Research Group (ERG), 2006). The table, below, describes the ATSDR sampling locations.

Table 1. Exposure Investigation Sampling Locations*

Site Number	Site Description	Measurement Type
1	Background (State Park)	$H_2S^{\dagger}$, VOC / 24-hour and 8-hour
2	Private Residence (Bridgeport)	H_2S, VOC / 24-hour and 8-hour (outdoors), H_2S, VOC/24-hour (indoors)
3	Private Residence (Petrolia)	H_2S, VOC / 24-hour and 8-hour (outdoors) H_2S, VOC / 24-hour (indoors)
4	City Park	H_2S, H_2S Collocated / VOC 24-hour (duplicate) and 8-hour
5	Private Residence (Bridgeport)	H_2S, VOC 24-hour and 8-hour
6	Elementary School	H_2S, VOC 24-hour and 8-hour

***Excerpted from the Exposure Investigation Protocol and Health and Safety Plan, ERG, 2006**
† H_2S= Hydrogen sulfide

2.4 *Data Quality Objectives*

Data Quality Objectives (DQOs) are established to ensure that the data collected during sampling are of sufficient quality to achieve the project goals. DQOs are used to design data collection procedures and decisions, including where to conduct monitoring, when to conduct monitoring, measurement frequency, and acceptable measurement precision and accuracy (ERG, 2006). The DQOs for this EI, information obtained during the site selection survey, and specifications associated with the monitoring and sample collection systems that were utilized are presented in Appendix C.

Measures of data validity include: data completeness, measurement precision, measurement accuracy, and system audits. Given our compliance with the DQOs, ATSDR has high confidence in our data for this sampling program. The specific evaluation tools for our EI are summarized below.

2.4.1. Data Completeness

Completeness refers to the number of valid measurements collected compared to the number of possible measurements expected from the continuous measurement and manual sampling methods conducted. Monitoring programs that consistently generate valid results have higher completeness than programs that consistently invalidate samples. The completeness of an air monitoring program, therefore, is a qualitative measure of the appropriateness and reliability of air sampling and laboratory analytical equipment and procedures, and a measure of the efficiency with which the program was managed (ATSDR, 2007).

During the four-week study period, the completeness of the monitoring network was very high, and exceeded the DQO of 80% data capture. Overall completeness was 97% (ATSDR, 2007). A table detailing the completeness at each sampling location can be found in Appendix C, Table 2.

2.4.2. Measurement Accuracy

Measurement accuracy for this project is defined as the ability to acquire the correct concentration from an instrument or sample analysis with an acceptable level of uncertainty while measuring a known concentration reference gas stream.

To determine the accuracy associated with the H_2S measurements acquired during this EI, a known concentration reference gas stream was measured. Pre- and post-deployment checks were calculated on each system to assess the measurement accuracy of each system. The difference between the concentrations measured by each instrument compared to the known concentration of the reference gas stream was calculated and expressed as % bias. As summarized in Appendix C, Table 3, the percent bias ranged from 0% to 1.49% during the pre- and post-deployment checks. These values are well within the DQO of ± 15% Bias (ATSDR, 2007).

2.4.3. Measurement Precision

Measurement precision is defined as the ability to acquire the same concentration from different instruments or samples while they are sampling the same gas stream, within an acceptable level of uncertainty. For this monitoring program, measurement precision for H_2S was assessed two ways: across instruments and between instruments. As part of the pre- and post-deployment quality control (QC) checks, the nine H_2S instruments simultaneously performed 10 concentration determinations of the same known concentration reference gas. The average concentration from the 10 determinations was calculated on an instrument-specific basis. Each instrument average was then compared to the standard deviation of its 10 concentrations and expressed as % Relative Standard Deviation (% RSD). The system precision RSDs range from 0.19% to 1.78% during the pre- and post-deployment checks. These values meet the DQO of 20% RSD (ATSDR, 2007). A table detailing the measurement precision for each monitor can be found in Appendix C, Table 3.

Measurement precision of the Air Toxics Compounds and SNMOC methods was determined by collecting two sets of duplicate samples at Site 4 and analyzing them in replicate. The average concentration for each set of duplicates and replicates was calculated for each compound identified. Each average was then compared to the standard deviation. The average % RSD was then determined for each Air Toxic Compound and SNMOC pollutant. Table 4 in Appendix C summarizes the precision calculations for Air Toxics Compounds and Table 5 summarizes those for SNMOCs. The DQO of ± 25% RSD was met overall for each method and per pollutant (ATSDR, 2007).

2.4.4 Other Data Quality Indicators

Accuracy for the Air Toxics Compounds analysis was established through performance audits prepared by and submitted to ERG by U.S. EPA as a regular function of the U.S. EPA National Air Toxics Monitoring Program that ERG manages and operates. Appendix C, Table 6 summarizes the audit results for Air Toxics Compounds. As presented in this table, all but one of the percent differences for Air Toxics Compounds are within ± 20%, thereby achieving DQO 8 presented in Appendix C, Table 1. Overall, the average percent difference (using absolute value) was slightly over 10% (ATSDR, 2007).

Throughout the study period, the SPM optical sensors were checked regularly (i.e., when the instruments were deployed, at the middle of the EI duration, and as the instruments were recovered) to ensure that the instrument was functioning properly. The acceptable operational range of response is from 10 to 13 milliamps (mA). As summarized in Appendix C, Table 7, the instrument response range fell within the acceptable performance range (ATSDR, 2007).

Note: Data collected every 60 seconds were analyzed in *rolling 30-minute averages* (an average of the previous 30 minutes for every observation) to be consistent with the averaging time of the critical study of ATSDR's acute MRL.

2.5 *Hydrogen sulfide sampling results*

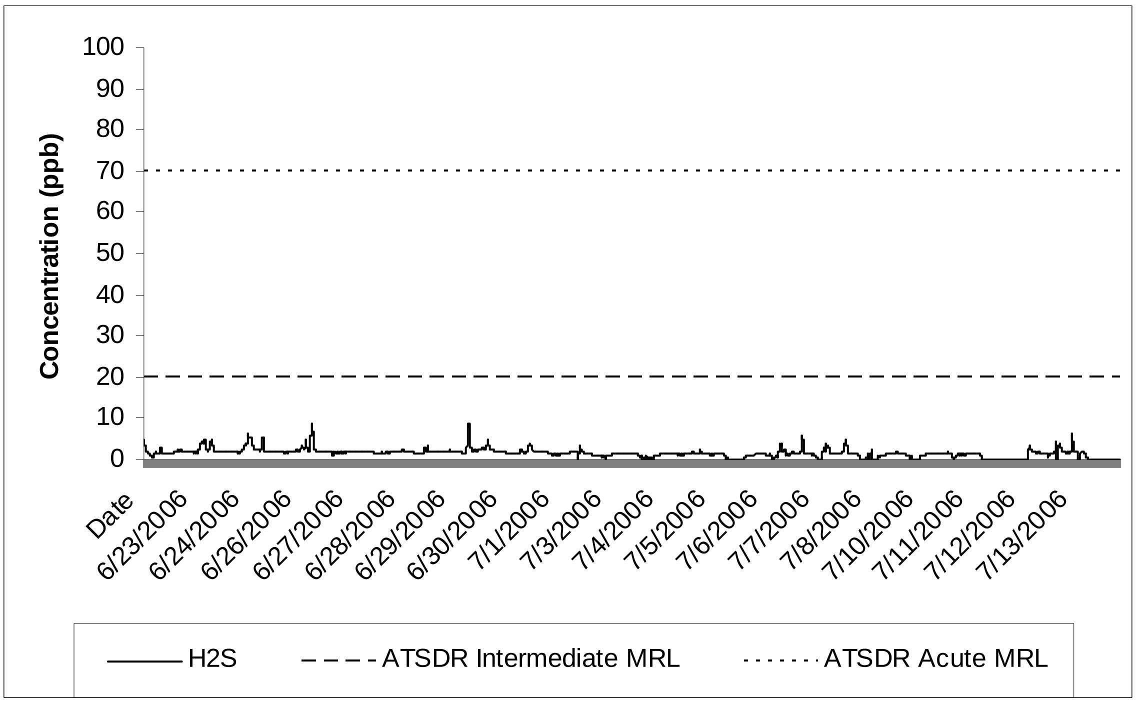
ATSDR sampled six locations for a total of four weeks, from June 22 to July 19, 2006. One of these locations was a background monitor at a state park, one was an elementary school, one was near City Park, and the remaining three were at residences (two in Bridgeport, one in Petrolia). To view sampling locations, see the map in Appendix B. At all locations except background, there was a clear *diurnal* (day/night) pattern; in other words, hydrogen sulfide concentrations were elevated at night. This is a common observation because winds are calmer at night and prevent the gas from being diluted and dispersed as efficiently as it typically is during the day. Wind and vertical mixing of air during the day help to disburse the gas and generally result in lower gas concentrations.

To evaluate the results of our data collection, ATSDR used health-based guidelines and a review of scientific studies to evaluate the public health risk posed by hydrogen sulfide. In our initial evaluation, the outdoor air data were compared to ATSDR minimal risk levels (MRLs) for acute or intermediate exposures (those occurring less than 14 days or from between 14-365 days). We further researched the significance of residential exposures by comparing concentrations of hydrogen sulfide in the Bridgeport area with those that were associated with human health effects in hydrogen sulfide exposure studies (see the Health Implications section of this document).

2.5.1. Background location (ATSDR Site 1)

The background location in this study was at Red Hills State Park. ATSDR selected this location because we believed that outdoor air in this natural setting would provide naturally occurring concentrations of hydrogen sulfide against which to compare those detected near facility operations. Background concentrations at this location were low, with the highest concentration of 11.5 ppb; 97% of detections in this location were 4 ppb or below. The 30-minute average trends, by date, are represented in Figure 1, below.

Figure 1. Trends of Hydrogen Sulfide-Background, Site 1- Red Hills State Park*

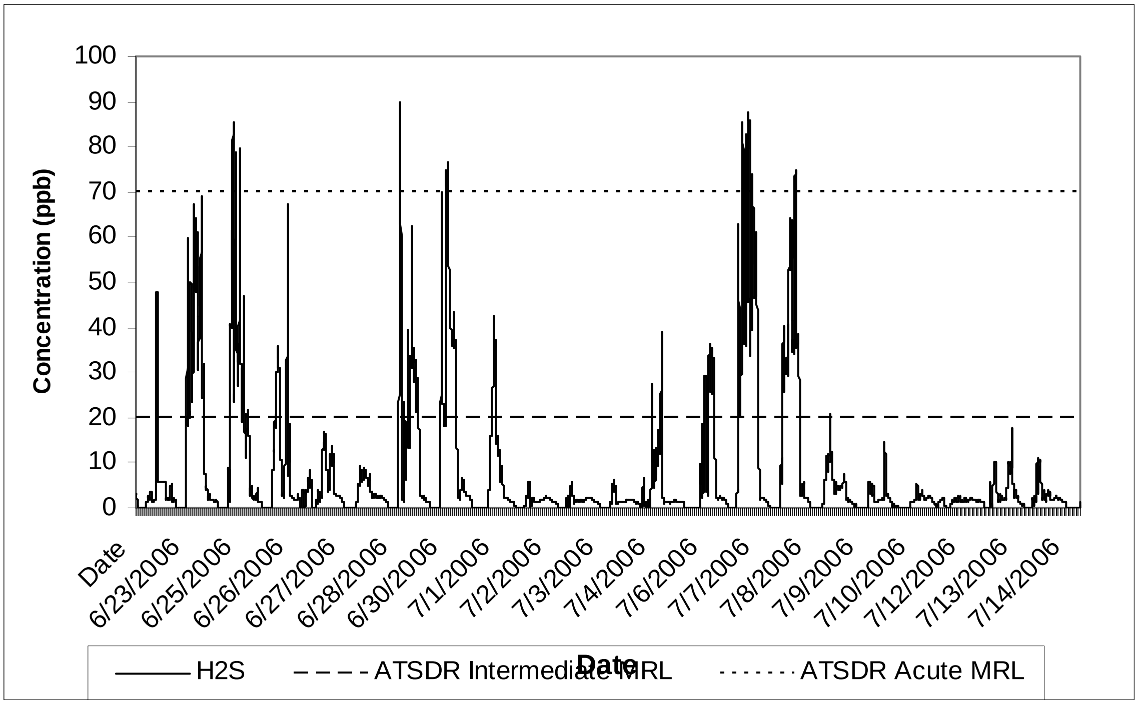


Data represent rolling 30-minute averages

2.5.2. Grade school location (ATSDR Site 6)

The majority of the time (81%), hydrogen sulfide levels were less than the 11.5 ppb maximum background concentration at this location. However, 14% of the time, concentrations exceeded the ATSDR intermediate MRL of 20 ppb, and 2% of the time they exceeded the acute MRL of 70 ppb. For over 6 hours of the study period, the monitors were at or above the upper detection limit of the monitor (90 ppb). Therefore, the actual highest concentrations could not be quantified. The 30-minute rolling average trends over the study period are plotted in Figure 2.

Figure 2. Trends of Hydrogen Sulfide, Site 6- Bridgeport Grade School*

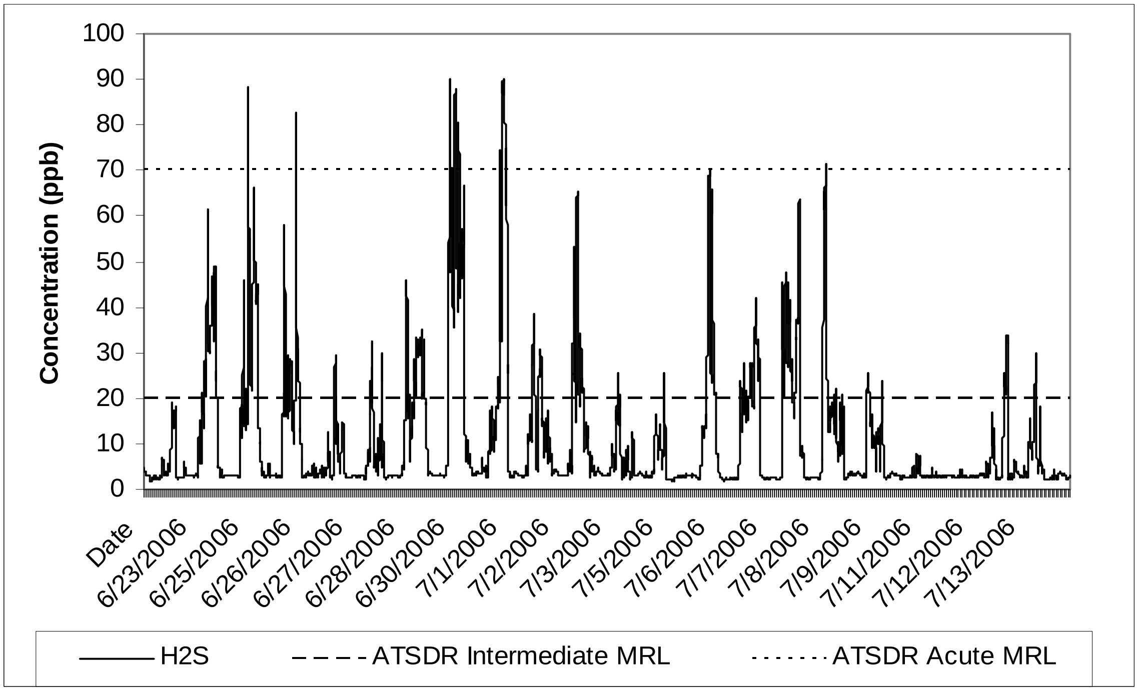


Data represent rolling 30-minute averages

2.5.3. City Park location (ATSDR Site 4C1)

This location was sited at City Park. The majority of the time (72%) hydrogen sulfide levels were less than the highest background concentration of 11.5 ppb. However, 18% of the time, concentrations exceeded that ATSDR intermediate MRL of 20 ppb, and 2% of the time they exceeded the acute MRL of 70 ppb (see Figure 3).

Figure 3. Trends of Hydrogen Sulfide-City Park, Site 4C1*



Data represent rolling 30-minute averages

2.5.4. Bridgeport locations

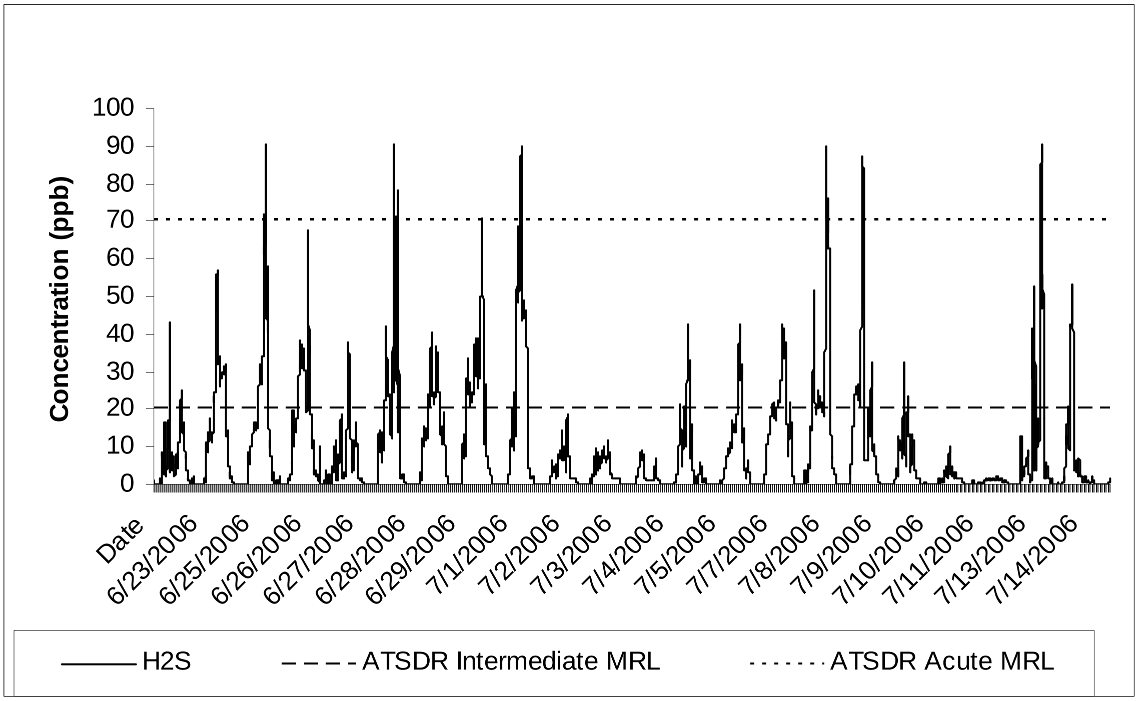
There were three monitors located at two residences in Bridgeport at monitoring sites 2 and 5. Site 2 had an indoor and outdoor monitor, and Site 5 had an outdoor monitor only. The indoor monitor had significantly lower concentrations than both of the outdoor monitors.

2.5.4.1 ATSDR Site 2

Outdoor monitor. The outdoor monitor at Site 2 detected significantly higher concentrations of hydrogen sulfide than the indoor monitor. For over five hours during the sampling period, outdoor concentrations of hydrogen sulfide exceeded the ATSDR monitor detection range of 90 ppb, thus the maximum concentrations of hydrogen sulfide at that location could not be quantified. Concentrations exceeded the maximum background concentration approximately 29% of the time. As with the previously mentioned sites, this location exceeded the ATSDR intermediate MRL of 20 ppb 18% of the time and the acute MRL of 70 ppb about 1% of the time. Figure 4 displays the 30-minute rolling averages at the outdoor monitor for Site 2.

Indoor monitor. Approximately 93% of the time, the indoor monitor detected concentrations less than the maximum background concentration of 11.5 ppb. The highest indoor detection at this location was 31 ppb. Concentrations exceeded the intermediate MRL of 20 ppb 1.5% of the time.

Figure 4. Trends of Hydrogen Sulfide-Bridgeport Residence, Site 2, Outdoor Air*

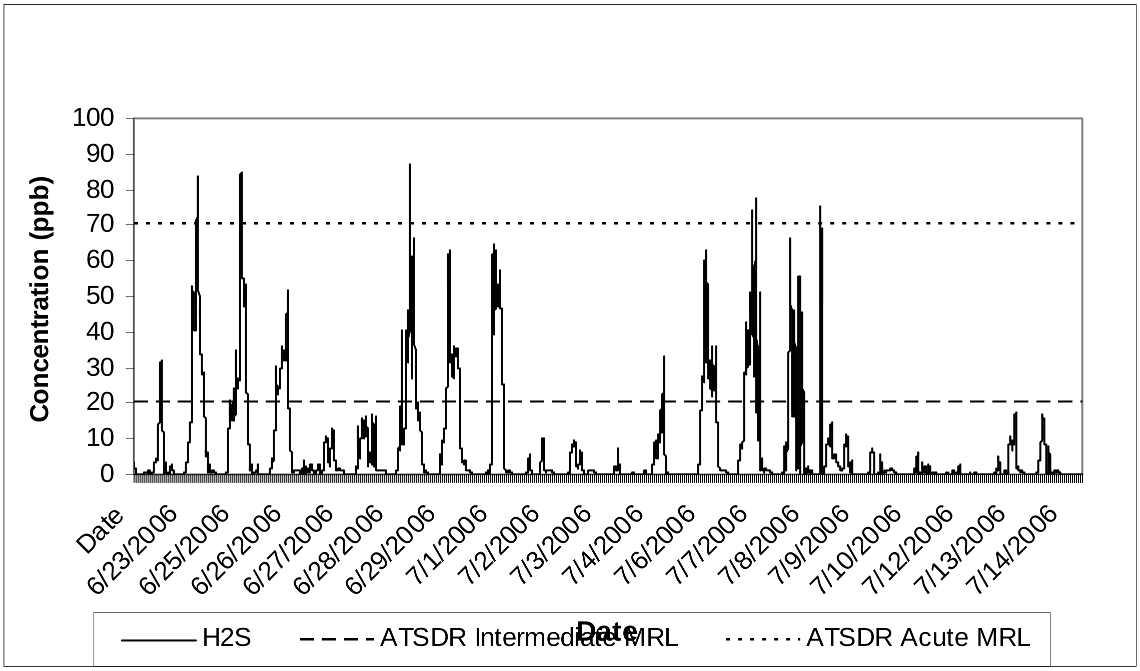


****Data represent rolling 30-minute averages***

2.5.4.2 ATSDR Site 5

The highest detection at the second Bridgeport residence was at or above the maximum instrument detection range of 90 ppb, and was detected for approximately three hours out of the four-week sampling period. Since this level exceeded the ATSDR monitor detection range, the maximum concentrations of hydrogen sulfide at that location could not be quantified. This location exceeded the intermediate ATSDR MRL of 20 ppb 14% of the time and the acute MRL of 70 ppb about 1% of the time. Concentrations at this location exceeded the background maximum of 11.5 ppb for 98% of the study duration. Figure 5 displays the 30-minute rolling averages at the outdoor monitor for Site 5.

Figure 5. Trends of Hydrogen Sulfide-Bridgeport Residence, Site 5, Outdoor Air*



***Data represent rolling 30-minute averages**

2.5.5. Petrolia location (ATSDR Site 3)

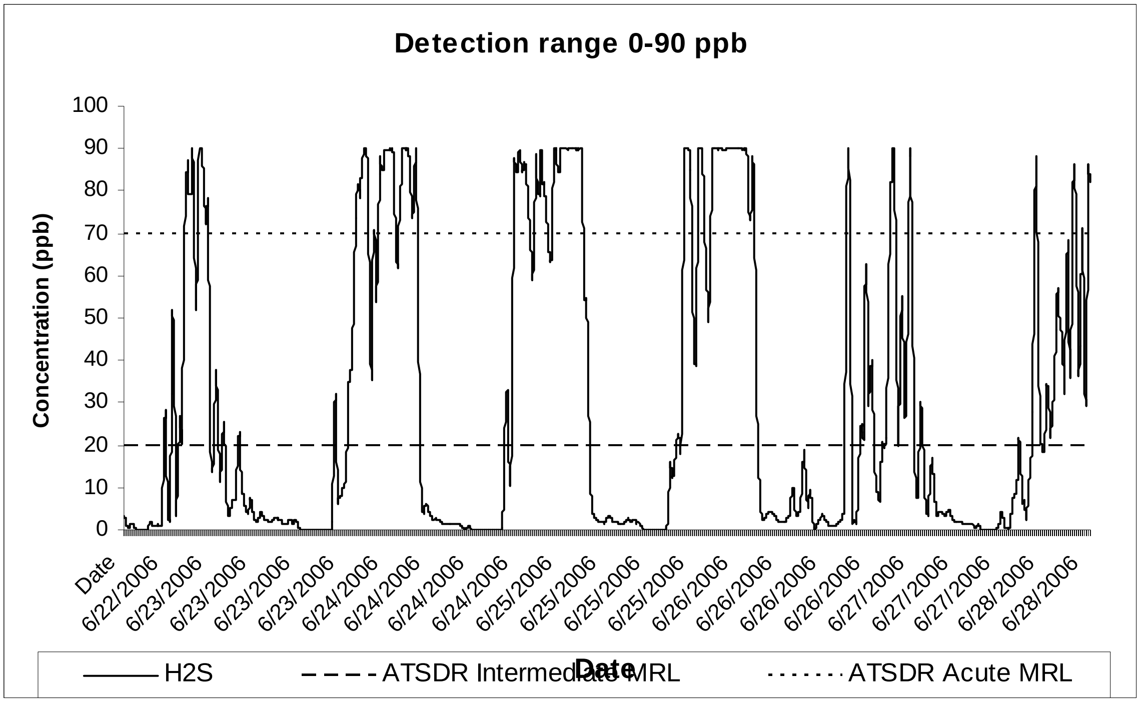
The highest concentrations of hydrogen sulfide were detected at the Petrolia residence. There were two monitors located at this residence, one indoors and one outdoors. This location was different than any of the others because the detection range was much higher. Initially, for the first eight days of sampling, the monitors were set at the lower detection range of 0-90 ppb. However, it was discovered that a large portion of the samples were at or above the upper detection range of the instruments, and were not being quantified (18% of the outdoor samples and 4% of the indoor samples). As a result, the range of detection for both monitors was changed to a higher detection range (53-1,500 ppb).

2.5.5.1 ATSDR Site 3, Outdoor monitor

Outdoor concentrations at this location reached 1,162 parts per billion of hydrogen sulfide during the study period. The outdoor concentrations at this location were significantly higher than any other location; only 1.7% of concentrations were *less* than the maximum background concentration of 11.5 ppb; 19% of concentrations were above the acute MRL of 70 ppb, and 11% were *above* 100 ppb. Concentrations were consistently in the hundreds of parts per billion; for example, levels were at or above 100 ppb for 49 hours during the four-week sampling period, and were above 300 ppb for 13.5 hours during the same period.

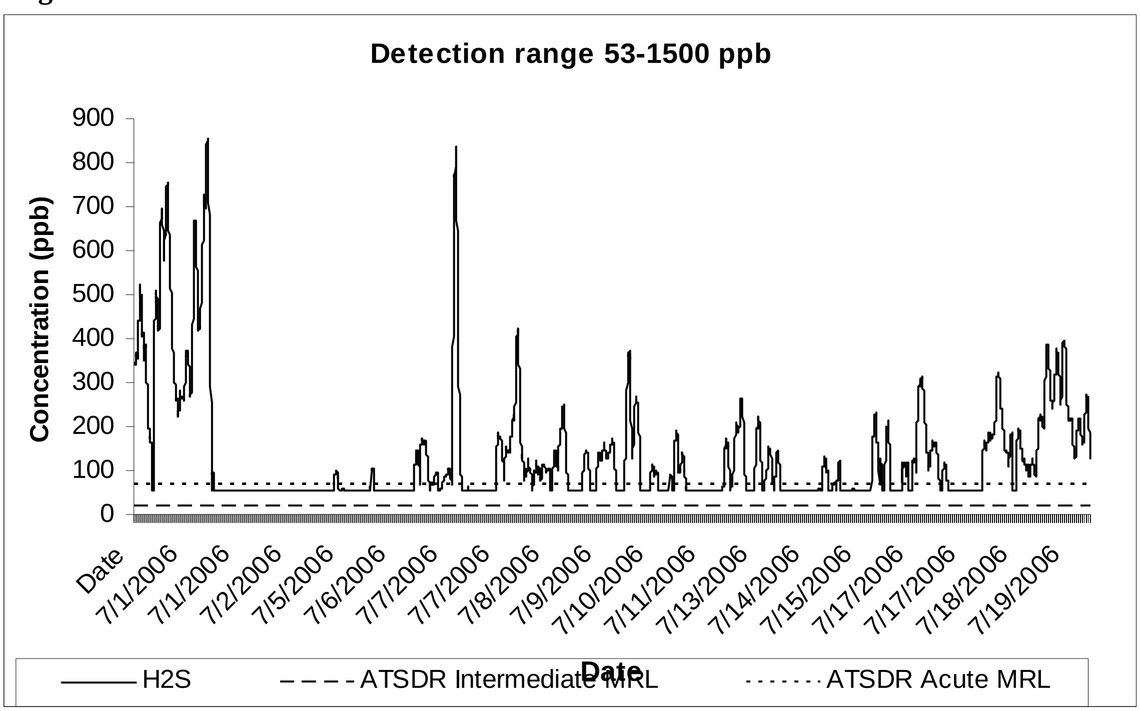
Trend charts of 30 minute rolling averages are shown in Figures 6a and 6b, before the Chem Key for higher detection was changed (6a), and one for afterward (6b).

Figure 6a. Trends of Hydrogen Sulfide- Petrolia Residence, Outdoor Air, 0-90 ppb detection range*



Data represent rolling 30-minute averages

Figure 6b. Trends of Hydrogen Sulfide- Petrolia Residence, Outdoor Air, 53-1,500ppb detection range*



Data represent rolling 30-minute averages

2.5.5.2 ATSDR Site 3, Indoor monitor

Although indoor concentrations at this location were lower than outdoor concentrations, levels exceeded the acute ATSDR MRL of 70 ppb for over 22 hours during the sampling period. As mentioned above, the two high range Chem Keys were installed into the indoor and outdoor monitors at this location after eight days to capture peak concentrations. The indoor monitoring trend chart is not listed due to longer periods of "noise" which are represented as 53 ppb, whether or not 53 ppb was actually detected. This monitor had a lower detection limit of approximately 53 ppb, thus while there were many detects of or near 53 ppb, they may be much lower. Due to this limitation in the data, we have low confidence in the lower detections at this site.

2.6 Organic compound sampling results

ATSDR collected VOC and SNMOC data at Site 2 indoors and outdoors. Samples were collected over an 8-hour and 24-hour period. While organic compounds characteristic of petroleum odors were present in all samples, such as isobutene, propane, butane, toluene, and xylenes, none were present at levels that posed a health concern (all were below their respective ATSDR health based guidelines).

3.0 U.S. EPA Air Investigation

The overall objective of the United States Environmental Protection Agency (U.S. EPA) monitoring during the summer of 2006 was to determine the levels of hydrogen sulfide in ambient air in the Bridgeport/Petrolia area. Data collection began in July of 2006, and is ongoing. However, this consultation will only address data collected in the summer of 2006. Hydrogen sulfide monitoring locations were selected based on several factors: expected high concentrations of hydrogen sulfide, U.S. EPA guidelines for placing a sample probe, monitoring location access, and the availability of utilities.

3.1 *Description of sampling equipment*

U.S. EPA collected hydrogen sulfide data at three residential locations, two of which were different than the ATSDR locations. All sampling stations were of similar design and the hydrogen sulfide analyzers and data loggers were housed within a controlled environment. The siting and operational parameters (an equivalent method adopted in 2002 by U.S. EPA) were in accordance with the EPA Quality Assurance Handbook for Air Pollution Measurement Systems (EPA-454/R-98-004, Vol. II, Part 1, Appendix 15). Data Quality Objectives were defined in the Bridgeport Quality Assurance Project Plan for hydrogen sulfide in the Bridgeport, Illinois area (U.S. EPA, 2006).

U.S. EPA measured hydrogen sulfide using a Thermo Environmental Instruments (TEI) and Advanced Pollution Instruments (API) continuous hydrogen sulfide/sulfur dioxide analyzers.

The analyzers are based on the Federal Equivalency Method (FEM) for measurements of sulfur dioxide, called *pulsed fluorescence* (40 CFR 53.1). In this FEM, ambient air sample is continuously drawn to an analyzer from a sample air inlet by a vacuum pump, routed to a sulfur dioxide scrubber where all sulfur dioxide is removed, and is then sent to a thermal converter where all hydrogen sulfide is oxidized to sulfur dioxide. Sulfur dioxide concentrations were captured and recorded continuously by an onsite Environmental Systems Corporation data logger. Data were collected in five minute average increments, and the detection range was a broad 1.4 ppb to 1,500 ppb.

U.S. EPA staff traveled to the Bridgeport/Petrolia area periodically to conduct span checks and calibrations at the three monitoring locations and to download data.

3.2 *Results*

Hydrogen sulfide data collected by U.S. EPA in the summer of 2006 were very similar to the general detection ranges measured by ATSDR. Below is a general description of results at the three locations. The values reported were for five minute averages, whereas ATSDR data were reported every minute. All three sampling locations were residences. Site 1 is in Petrolia, whereas Sites 2 and 3 were immediately to the north and northwest of the City of Bridgeport. See a map of the sampling locations in Appendix B.

3.2.1. U.S. EPA Site 1 (Petrolia)

Hydrogen sulfide concentrations at this location were collected between July 9 and August 21, 2006. At this location, the highest concentration detected was 872.9 ppb over five minutes. Hydrogen sulfide concentrations exceeded 100 ppb for approximately 72 hours during the sampling period; they exceeded the ATSDR acute MRL of 70 ppb for approximately 103 hours during the sampling period, and exceeded the ATSDR intermediate MRL of 20 ppb for approximately 203 hours during the same period (U.S. EPA, 2006).

3.2.2. U.S. EPA Site 2 (North Bridgeport)

Hydrogen sulfide concentrations at this location were collected between July 20 and August 21, 2006. During this time period, significant issues arose regarding instrument accuracy. Despite these limitations, the highest corrected concentration detected was 416.3 ppb over five minutes. Hydrogen sulfide concentrations exceeded 100 ppb for approximately 15 hours during the sampling period; they exceeded the ATSDR acute MRL of 70 ppb for approximately 26 hours during the sampling period, and exceeded the ATSDR intermediate MRL of 20 ppb for approximately 73 hours during the same period (U.S. EPA, 2006).

3.2.3. U.S. EPA Site 3 (Northwest Bridgeport)

Hydrogen sulfide concentrations at this location were collected between August 22 and October 12, 2006. At this location, the highest concentration detected was 118.1 ppb over five minutes. Hydrogen sulfide concentrations exceeded 100 ppb for 10 minutes during the sampling period; they exceeded the ATSDR acute MRL of 70 ppb for approximately 40 minutes during the sampling period, and exceeded the ATSDR intermediate MRL of 20 ppb for approximately 17 hours during the same period (U.S. EPA, 2006).

4.0 Discussion

4.1 *Evaluation of Environmental Data*

As mentioned previously, ATSDR used health-based guidelines and a review of scientific studies to evaluate the public health risk posed by hydrogen sulfide. In our initial evaluation, the outdoor air data were compared to ATSDR minimal risk levels (MRLs) for acute or intermediate exposures (those occurring less than 14 days or from between 14-365 days).

ATSDR also evaluated occupational and epidemiologic studies of human exposures, and sometimes discusses the lowest observed adverse effect level (LOAEL) and no observed adverse effect level (NOAEL). The LOAEL is the lowest exposure in a study that resulted in a measurable health effect. A NOAEL is the highest exposure in a study that ***did not*** result in a measurable health effect. Often, ATSDR and EPA health based guidelines are based on LOAELs and NOAELs.

4.2 *Limitations of Exposure Investigation*

Exposure Investigations are designed to characterize the magnitude of exposures to an environmental contaminant. However, there are always limitations in conducting these investigations due to the duration of sampling and the number of locations to be sampled. This investigation attempted to evaluate both the typical exposures within the Bridgeport community as well as areas that may represent the highest levels of exposure. Also, the selection of four weeks in June-July 2006 was intended to represent the periods of most significant potential for outdoor and indoor exposure.

A specific data limitation was the detection ranges of the tape meters used to measure hydrogen sulfide concentrations. As described in the methods section, the instruments were set in either a 0-90 ppb (low) or a 53-1,500 ppb (high) range. At some locations with the instruments set in the low range, the concentrations of hydrogen sulfide frequently exceeded 90 ppb but could not be quantified. With instruments in the high range, the concentrations below 50 ppb could not be quantified. As a result, there is some uncertainty in characterizing the magnitude of exposure to hydrogen sulfide over the entire sampling period. However, the air monitoring conducted by U.S. EPA using a method with a broader detection range generally confirmed the concentrations detected with the tape meters and provide further support for the conclusions of the EI.

Lastly, hydrogen sulfide and SNMOC/VOCs were the only compounds sampled. Sulfuric acid and sulfur dioxide, both potentially significant byproducts of oil and gas industry operations, were not sampled for. These compounds may contribute to the health effects and damage to personal property being reported by area residents.

4.3 *Health Implications*

4.3.1 Health Effects of Hydrogen Sulfide

Hydrogen sulfide has been documented to cause a number of health effects in humans and animals. The severity of the health impacts is related to the magnitude, frequency, and duration of the exposure. In epidemiologic studies, exposures are generally categorized as acute, intermediate, or chronic. ATSDR defines acute as an exposure lasting less than 14 days, intermediate exposure is an exposure of 14-365 days, and chronic exposure is an exposure that lasts longer than one year (ATSDR, 2006c). People living in communities impacted by industrial emissions of hydrogen sulfide are more likely to have chronic exposures with intermittent acute odor events. Typical concentrations in communities with hydrogen sulfide sources range from low ppb to low ppm concentrations. Data collected during this EI documented exposures from 0 ppb to 1162 ppb at various locations in the greater Bridgeport area.

Short-term exposures to high levels of hydrogen sulfide may cause adverse health effects. For example, one scientific study demonstrated bronchial constriction in two out of 10 asthmatics exposed to 2,000 ppb hydrogen sulfide for 30 minutes (Jappinen, Vilkka, Marttila, and Haahtela, 1990). Other studies also document changes in oxygen uptake (Bhambini & Singh, 1991), and an inhibition of the aerobic capacity of muscle tissue in healthy men exposed to between 5,000 and 10,000 ppb for short periods of time (Bhambini, Burnham, and Snydmillar, 1996a, 1996b). Decreased lung function was observed in sewer workers as compared to water treatment plant workers not exposed to hydrogen sulfide (Richardson, 1995).

Although only measured at extremely high levels at problematic wells and gas lines, hydrogen sulfide has been detected at area well heads and compromised flare lines at levels up to 2,000,000 ppb (ATSDR, 2006b). Since many wells and flare lines are easily accessible by area residents, extremely high exposures are possible, even though prolonged elevated exposures are unlikely. Prolonged exposure to high levels of hydrogen sulfide can cause olfactory fatigue at high concentrations, typically between 100,000-150,000 ppb (Hirsch & Zavala, 1999; Reiffenstein, Hulbert, and Roth, 1992), and severe injury or death for even very brief exposures to concentrations of 500,000-1,000,000 ppb (EPA, 2003; IRIS, 2003). Acute exposures to elevated levels of hydrogen sulfide can result in central nervous system effects including dizziness, nausea, headache, and physical collapse (Milby & Baselt, 1999; Parra et al., 1991; Snyder et al., 1995; Tvedt et al., 1991).

Hydrogen sulfide gas is an eye irritant (ATSDR, 2006c). Keratoconjunctivitis (inflammation of the *cornea*- the clear outer lining of the eye, and *conjunctiva*-membrane that lines the eyelid and eye), punctate corneal erosion (deterioration of the cornea), blepharospasm (spasm of the orbicular muscle of the eyelid), lacrimation (the secretion of tears from the tear ducts), and photophobia (visual intolerance to light) have developed in individuals exposed to brief high-level concentrations of hydrogen sulfide gas (Ahlborg, 1951; Luck & Kaye, 1989). A retrospective study of 250 Canadian workers who submitted workers' compensation claims for hydrogen sulfide exposure found that 18% had developed conjunctivitis, which in some cases persisted for several days (Arnold, Dufresne, and Alleyne, 1985). Although acute exposure to hydrogen sulfide may result in eye irritation, none of these reports of ocular exposure demonstrate permanent eye damage to the individuals exposed (Andeau, Gnanaharan, and Davey, 1985; Arnold et. al, 1985; ATSDR, 2006c; Deng and Chan, 1987; Luck and Kaye, 1989; Stine, Slosberg, and Beacham, 1976). Eye irritation has been observed in animals exposed to 20,000 ppb and 400,000 ppb hydrogen sulfide during one- and four-hour periods, respectively (Haider, Hasan, and Islam, 1980; Lopez, Prior, and Yong, 1988). Animals exposed for three months experienced ocular effects levels as low as 8,500 ppb hydrogen sulfide (Chemical Industry Institute of Technology [CIIT], 1983; Curtis, Anderson, and Simon, 1975).

Long-term exposures to hydrogen sulfide may also result in adverse health effects. For example, neurological effects resulting from chronic-duration exposure to hydrogen sulfide in the shale industry have been reported. Symptoms in workers exposed to daily concentrations of hydrogen sulfide (which often exceeded 20,000 ppm) included fatigue, loss of appetite, headache, irritability, poor memory, and dizziness (Ahlborg, 1951). A recent study examining health effects in a community exposed to low levels of hydrogen sulfide has noted that after days when hydrogen sulfide levels are above 30 ppb, there is an increase in asthma-related hospital visits among children (Campagna, Kathman, Pierson, Inserra, Phifer, Middleton, Zarus, and White, 2004). Kilburn and Warshaw (1995) studied chronic exposures to sulfide gases in oil processing plants and found that people working at the plant or living downwind at the plant experienced nausea, headache, vomiting, breathing abnormalities, nosebleeds, depression, and personality changes at levels between 10 ppb and 100 ppb. Kilburn (1997) published a second study documenting previous acute or chronic exposure to sulfur gases and impaired neurobehavioral function (16 months-years). Mood and the frequency of a battery of symptoms were evaluated. The study results suggested that cognitive disability, reduced perceptual motor speed, impaired memory, and abnormal mood status were related to historical hydrogen sulfide exposure (Townsend, 1998).

4.3.2 Community Exposures

Residents of the Bridgeport and Petrolia Communities report that they have been experiencing symptoms they believe are related to chronic hydrogen sulfide exposure (ATSDR meeting with Residents, April 2006). Many of the symptoms they have reported are consistent with effects reported at similar levels of exposure to hydrogen sulfide in outdoor air. The odor of hydrogen sulfide itself has been associated with a number of mild neurological symptoms. Additionally, scientific studies have reported that levels similar to those detected in the community have resulted in health effects in long or short-term exposure scenarios to study populations, as discussed in this section. Therefore, chronic exposure to hydrogen sulfide in homes and in outdoor air could potentially cause many of the health effects mentioned in this section.

Residents in the Bridgeport and Petrolia areas are at increased risk of respiratory and neurological health impacts from emissions from PennTex operations. At most sites, 10% of readings exceed the ATSDR intermediate MRL of 20 ppb. Data from the Petrolia location documented the most elevated outdoor exposures in our study. Because these exposures are frequent and persistent, exposures in Bridgeport and Petrolia represent a public health hazard. Steps should be taken immediately to address sources of exposures in the community and significantly reduce community exposures to hydrogen sulfide.

4.4 *Child Health Considerations*

ATSDR recognizes that in communities faced with contamination of their air, water, soil, or food, the unique vulnerabilities of infants and children demand special emphasis. ATSDR is committed to evaluating the health impact of environmental contamination on children, and uses health guidelines in its investigations that are protective of children. *Outdoor concentrations of hydrogen sulfide in the community present an unacceptable risk to children's health in the area, particularly for children with compromised respiratory systems.*

4.5 *Physical Hazards*

There is a risk of fire and explosion for adults and children if there is an ignition source within close contact of oil wells in the area. Also, given that many of the wells are easily accessible and unfenced, they may represent a physical hazard for children playing near or on the well. Residents should avoid close contact with area wells, flare lines, and collection facilities to prevent injury.

5.0 Conclusions

- Peak concentrations of hydrogen sulfide measured in Bridgeport and Petrolia during the exposure investigation represent a public health hazard to residents and school children in the area.
- SNMOCs/VOCs detected in the air sampling indicate the presence of oil vapors; however, measured concentrations of these chemicals do not represent a health hazard to area residents.
- The lack of fencing around most of the wells and storage facilities represents a physical hazard to area residents, particularly children.

6.0 Recommendations

- PennTex and other gas companies should take action immediately to implement improved emission control measures that will significantly reduce the levels of exposure to hydrogen sulfide gas released from oil wells, emergency pits, and oil storage facilities.
- U.S. EPA, state agencies, and PennTex should coordinate to implement an air monitoring program to verify the effectiveness of these emission control measures in reducing the release of hydrogen sulfide gas. The data from this monitoring should be accessible in real time so that appropriate warnings and interventions can be initiated during

conditions of high gas concentrations. This program should include efforts to characterize sulfur dioxide in ambient air.

- PennTex should restrict access to wells in populated areas to reduce physical hazards to trespassers and children.
- Residents should avoid close contact with area wells, flare lines, and collection facilities.

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PennTex Resources

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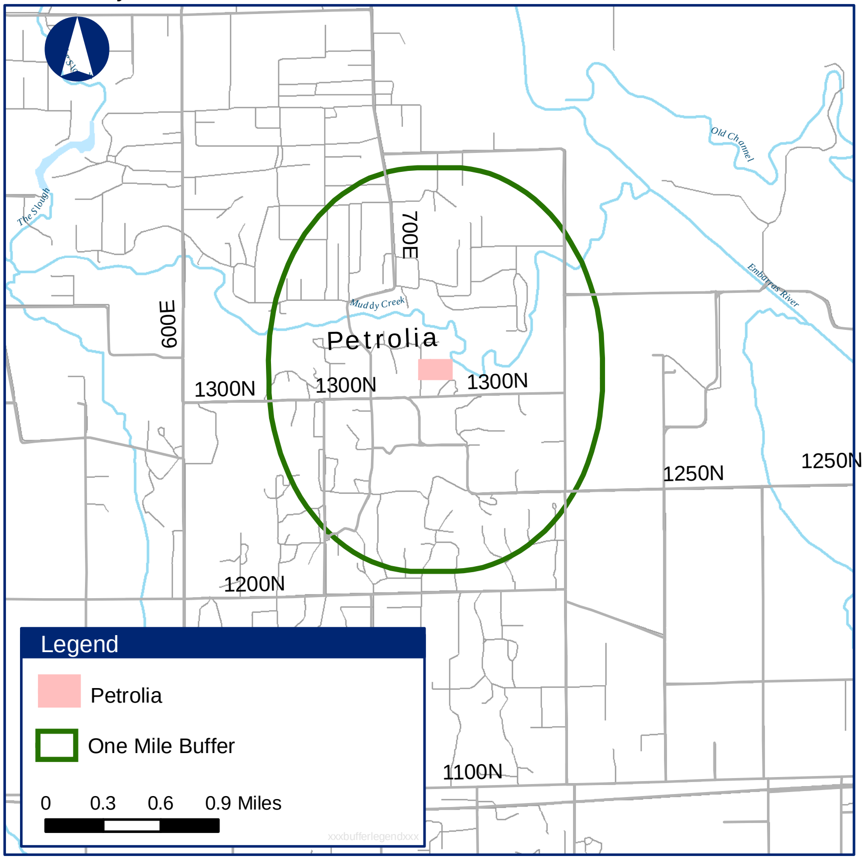


Site Location: Lawrence County, IL

Demographic Statistics

Within Area of Concern*

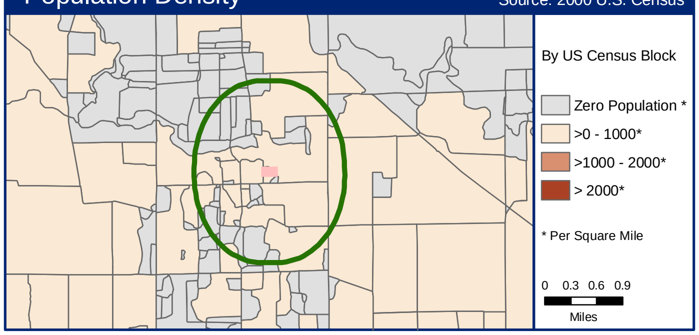
	1mi Petrolia*
Total Population	162
White Alone	161
Black Alone	0
Am. Indian & Alaska Native Alone	0
Asian Alone	0
Native Hawaiian & Other Pacific Islander Alone	0
Some Other Race Alone	0
Two or More Races	1
Hispanic or Latino**	0
Children Aged 6 and Younger	14
Adults Aged 65 and Older	24
Females Aged 15 to 44	37
Total Housing Units	68

Base Map Source: Geographic Data Technology, May 2005.
Site Boundary Data Source: ATSDR Geospatial Research, Analysis, and Services Program, Current as of Generate Date (bottom left-hand corner).
Coordinate System (All Panels): NAD 1983 StatePlane Illinois East FIPS 1201 Feet

Demographics Statistics Source: 2000 U.S. Census
* Calculated using an area-proportion spatial analysis technique
** People who identify their origin as Hispanic or Latino may be of any race.

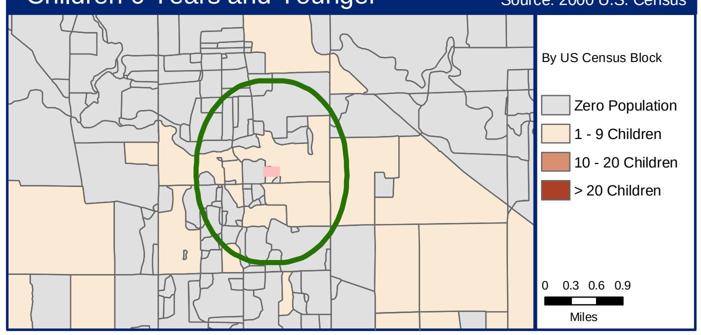
Population Density

Source: 2000 U.S. Census



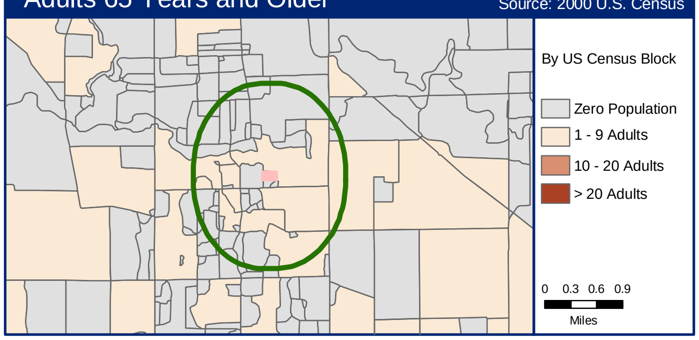
Children 6 Years and Younger

Source: 2000 U.S. Census



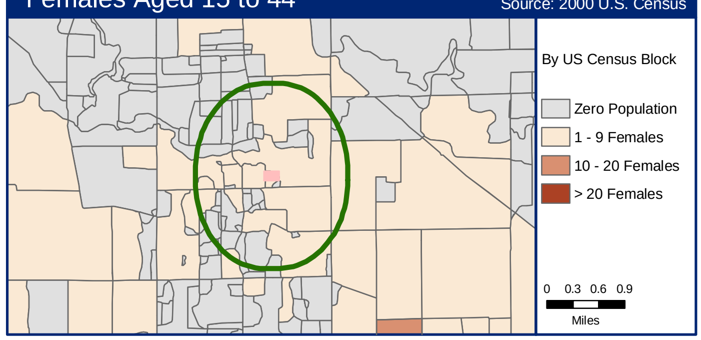
Adults 65 Years and Older

Source: 2000 U.S. Census



Females Aged 15 to 44

Source: 2000 U.S. Census



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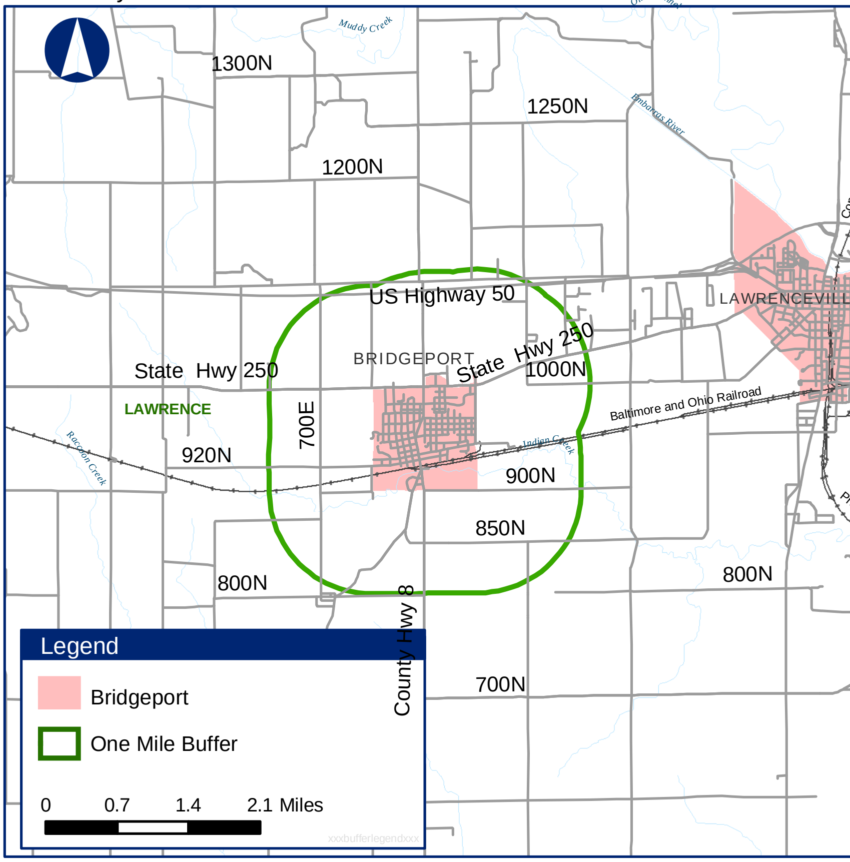
PennTex Resources
Bridgeport, IL

EPA Facility ID: UNAVAILABLE



Site Location: Lawrence County, IL

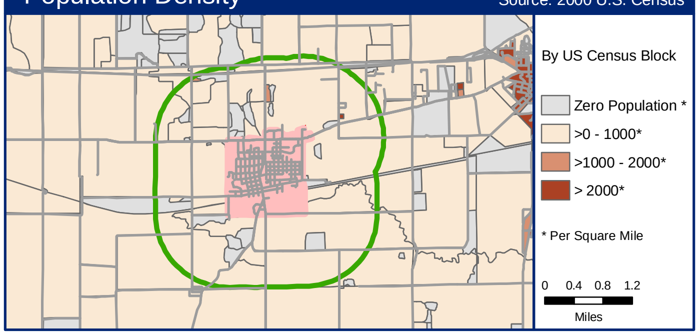
Demographic Statistics
Within Area of Concern*

	1mi Bridgeport
Total Population	2,774
White Alone	2,733
Black Alone	14
Am. Indian & Alaska Native Alone	5
Asian Alone	0
Native Hawaiian & Other Pacific Islander Alone	0
Some Other Race Alone	2
Two or More Races	20
Hispanic or Latino**	11
Children Aged 6 and Younger	225
Adults Aged 65 and Older	519
Females Aged 15 to 44	555
Total Housing Units	1,239

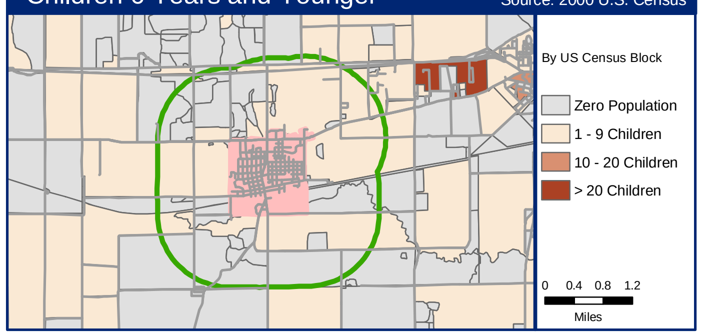
Base Map Source: Geographic Data Technology, May 2005.
Site Boundary Data Source: ATSDR Geospatial Research, Analysis, and Services Program, Current as of Generate Date (bottom left-hand corner).
Coordinate System (All Panels): NAD 1983 StatePlane Illinois East FIPS 1201 Feet

Demographics Statistics Source: 2000 U.S. Census
* Calculated using an area-proportion spatial analysis technique
** People who identify their origin as Hispanic or Latino may be of any race.

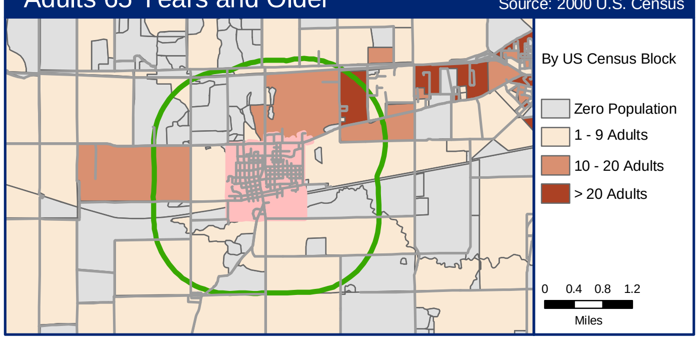
Population Density
Source: 2000 U.S. Census



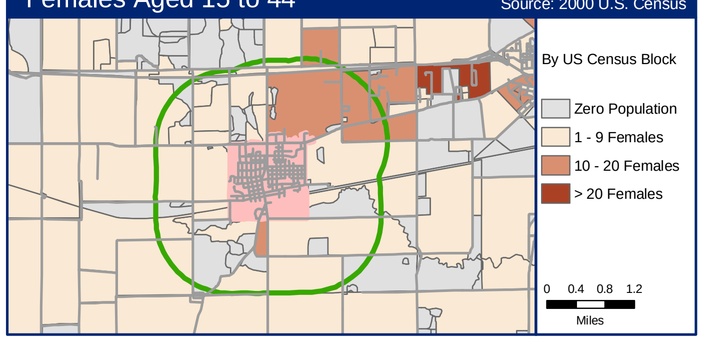
Children 6 Years and Younger
Source: 2000 U.S. Census



Adults 65 Years and Older
Source: 2000 U.S. Census



Females Aged 15 to 44
Source: 2000 U.S. Census



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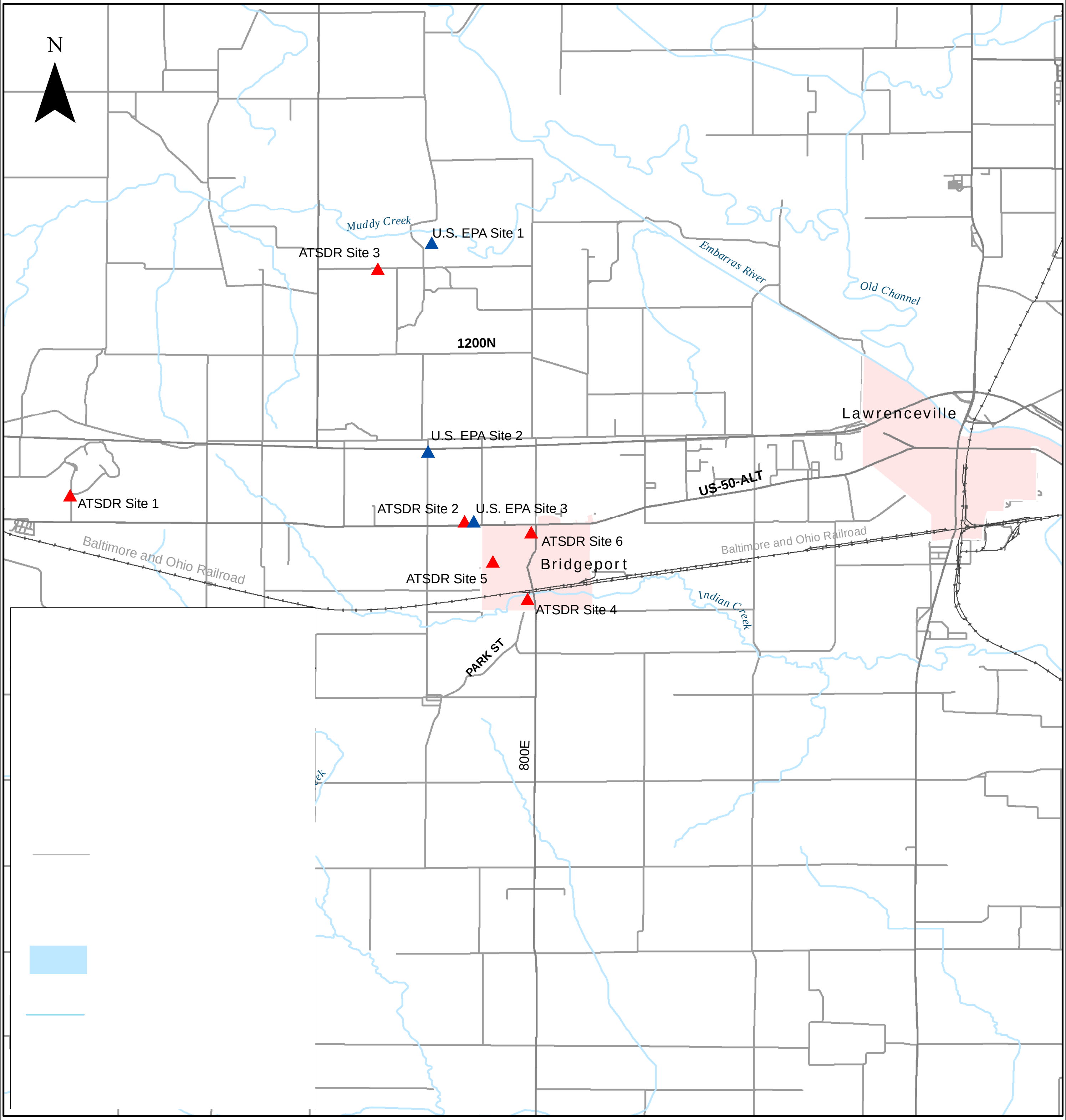

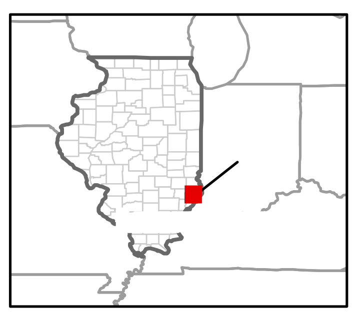

PennTex Resources

Bridgeport, Illinois

VICINITY MAP

Base Map Source: 1995 TIGER/Lines Files

GRASP
GEOSPATIAL RESEARCH, ANALYSIS & SERVICES PROGRAM

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