Attachment 7 Example Exposure Investigation Report

Private Well Water Sampling to Assess Water Quality Issues
Posey County, Indiana

Cost Recovery Number: A0ZH

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Prepared by:

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Abbreviations and Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CDC	Centers for Disease Control and Prevention
COC	Contaminant of Concern
CREG	Cancer Risk Evaluation Guide
CV	Comparison Value
DCHI	Division of Community Health Investigations
DOI	Department of the Interior
DRO	Diesel Range Organic compound
EI	Exposure Investigation
EMEG	Environmental Media Evaluation Guide
IDEM	Indiana Department of Environmental Management
IDEM RISC	IDEM Risk Integrated System of Closure
IDNR	Indiana Department of Natural Resources
IOM	Institute of Medicine
MCL	Maximum Contaminant Level
mg/L	Milligrams per liter
MRL	Minimal Risk Level
MRO	Motor Range Organic compounds
NHANES	National Health and Nutrition Examination Survey
QA/QC	Quality Assurance/Quality Control
PAH	Polycyclic Aromatic Compound
PCDOH	Posey County Department of Health
pCi/L	Picocurie per liter
RL	Reporting Limit
RMEG	Reference Dose Media Evaluation Guide

RSL	Regional Screening Level
SMCL	Secondary Maximum Contaminant Level
TDS	Total Dissolved Solids
TPH	Total Petroleum Hydrocarbons
µg/L	Micrograms per liter
US EPA	United States Environmental Protection Agency
USGS	United States Geological Society
USGS NWIS	USGS National Water Information System
USGS NWQL	USGS National Water Quality Laboratory
VOC	Volatile Organic Compound
WHO	World Health Organization

Executive Summary

Background/Request

Extensive oil and natural gas production has occurred in Posey County, IN since the 1930s. In 2008, area residents complained to the Indiana Department of Environmental Management (IDEM) about petroleum and oil field brine (i.e., salt) contamination in private drinking water wells. In January 2010, IDEM collected water samples from ten private/residential drinking water wells in Posey County, near the City of Mount Vernon and performed a limited chemical analysis. Samples from eight of the ten wells contained total petroleum hydrocarbons (TPH) above an IDEM comparison level. Chloride concentrations that exceeded the Secondary Maximum Contaminant Level (SMCL) were reported in three of the ten wells (IDEM, 2010).

At the request of IDEM, the Agency for Toxic Substances and Disease Registry (ATSDR) conducted an Exposure Investigation (EI) to evaluate water quality in residential private wells located near Mount Vernon in Posey County, IN. In June 2012, ATSDR collected well water samples for chemical analysis for water quality indicators, major ions, elements, alpha radiation, petroleum-related constituents and methane The water samples were collected from untreated well water.

The water in some of the wells tested may not be suitable for drinking and cooking (SMCL exceedances, presence of TPH and Oil and Grease), may be of health concern for some individuals (elevated concentrations of salts, metals, and radiation), and may be an explosive hazard (methane gas).

Individual test results were provided to participants prior to this EI report.

A limitation of the EI is that the results are only applicable to the wells tested and only representative of the time period in which they were tested. The results cannot be generalized to other populations because this investigation focused on people in the Posey County area located in proximity to the Mount Vernon Consolidated Oil Field. Results cannot be used to determine the source of contaminantion. In addition, results of this EI cannot be used to predict the past, current, or future occurrence of disease in individuals.

Additional limitations of the EI include that only one round of sampling was collected and evaluated (although the results were consistent with the results IDEM found during their sampling in 2010) and that only ten of the thirty homes were tested for petroleum-related contaminants.

Wells Tested

Thirty homes were identified in the area that was previously tested by IDEM. To be eligible for the EI, participants were required to have a private well that was their primary source of household water. At one location, the homeowner requested that a non-drinking water well be tested instead of their drinking water well, resulting in 29 wells being evaluated in this EI. The water was sampled prior to any filtration system so the results are indicative of the groundwater source. If the home had a filtration system, the sampled water may not be indicative of the water that the participants use in their home.

Findings

ATSDR concludes that the water in some of the wells tested may not be suitable for drinking and cooking (SMCL exceedances, presence of TPH and Oil and Grease), may be of health concern for some individuals (elevated concentrations of salts, metals, and radiation) and may be an explosive hazard (methane gas).

More specific findings are described in the following summary.

- Health-related findings:
    - Methane in well water was elevated in nine of ten of the private wells tested. Safety is the main concern associated with methane gas because it is a fire and explosive hazard. If present, methane can be released from water into the air during everyday household activities. If methane gas builds up to a high enough level in an area that is not well ventilated, a spark or ignition source can cause a fire or explosion. Methane gas that builds up in an enclosed space can also displace of oxygen in the room and the lack of oxygen may make it difficult to breathe. This would only happen with a very high buildup of methane in an unventilated room.
    - Salts, iron and lithium were elevated in many of the wells. Elevated levels of these contaminants may be a concern for sensitive individuals (e.g., children, pregnant women) or people on salt- or iron-restricted diets and those who are taking lithium for medical purposes. These contaminants likely are not a health issue for persons that are not part of these sensitive populations. The salt and iron may also result in water quality/potability issues, including a bad taste and the staining of plumbing fixtures.

- Manganese in two of the 30 wells was found at a level that may be associated with behavioral and neurological effects in infants and children when ingested over several years, based on case reports in the scientific literature. Manganese can also result in a bad taste to the water and the staining of plumbing fixtures.

- Alpha radiation was found in three of 26 wells tested for at concentrations above the comparison level. The measurement of alpha radiation is intended to provide information on the presence of alpha radiation, but does not define the particular radionuclide that may be emitting the alpha radiation so a specific risk value cannot be determined. Beta radiation levels were found below the comparison level in all tested wells. The comparison levels for radiation exposure are based on an increased risk of cancer over a lifetime. Radiation occurs naturally in the environment.

- Arsenic was found in some private wells at levels below EPA's Maximum Contaminant Level (MCL) (the regulatory level for public water systems) but above ATSDR's long-term, health-based comparison level. Although the levels in the wells were found below the MCL, drinking water with these levels may still pose a low health risk over a lifetime of use. Arsenic is a naturally occurring element and was found in the water at levels typical of the Posey County area.

- Water quality findings:
  - Water from many wells tested contained high concentrations of contaminants including high pH, total dissolved solids (TDS), salts, iron, and manganese. These contaminants can result in a bad taste or smell and can stain plumbing fixtures. Salts, iron, arsenic, and manganese may also result in health effects (see previous section).

  - Ten of the wells with an oily sheen and/or bubbling water were tested for petroleum-related contaminants. Total petroleum hydrocarbons (TPH) were elevated in 8 of the 10 water samples and the presence of oil and grease was detected in all 10 samples. Based on the methods used and the results reported, there is evidence that dissolved and degraded miscible petroleum is in water in the investigation area. The presence of petroleum-related contaminants along with methane in the well water in the area indicates that the drinking water is likely not suitable for drinking.

Recommendations

ATSDR is making the following recommendations:

1. Residents located in the EI investigation area that are experiencing poor quality water (e.g., smells or tastes bad, bubbly, noticeable oil sheen), should reduce their exposure to contaminants in well water by using another source of water for drinking and cooking (e.g., bottled water). Residents that are concerned about the quality of their water may contact IDEM for further information on testing and treatment options.

2. Until another source of water can be obtained:

    - Residents on salt-or iron-restricted diets, or who are taking lithium for medical reasons, or have sensitive individuals (e.g., children, pregnant women) living in the home, should consult their physicians about the elevated amounts of these contaminants in their well water.

    - Residents with formula-fed infants should make infant formula with bottled water instead of tap water given the elevated concentration of manganese in their well water.

3. Based on the amount of methane detected in area groundwater:

    - Monitor their water for the presence of methane gas by checking their water for bubbles, or a cloudy or milky appearance.

    - Vent their wellheads and their homes to lower the risk of explosion or fire associated with the buildup of methane gas in the home.

    - Install a combustible gas detector in their home to monitor the level of gas in their homes, using manufacturer's recommendations for placement and use.

Purpose of the Exposure Investigation

The purpose of this Exposure Investigation (EI) was to test private well water in homes located near Mount Vernon, in Posey County, IN. The Indiana Department of Environmental Management (IDEM) requested ATSDR assistance in this effort. Wells were tested to determine the presence of chemical contaminants in the water that could impact the health of residents and may be associated with the presence of crude oil and natural gas in the region. The well water testing was conducted using validated, state-of-the-science analytical methodologies. Results of this investigation were used to inform the residents if their well water has contaminants above established comparison levels or at levels that may cause harm.

Limitations

The results of this investigation are only applicable to the 29 wells tested. The results cannot be generalized to other populations because this investigation attempts to specifically target people in the Posey County area located in proximity to the Mount Vernon Consolidated Oil Field (Figure 1 in Appendix A). Based on their location, these wells have the potential to contain higher concentrations of petroleum-related contaminants, resulting in a higher likelihood of exposure for the residents using the water as a source of household water.

Additional limitations of the EI include that only one round of sampling was evaluated (although the results were consistent with the results IDEM found during their sampling in 2010) and that only ten of the thirty homes were tested for petroleum-related contaminants.

Background

Activities associated with oil and natural gas production have the potential to affect freshwater aquifers and wells that are the sole source of drinking water for many rural residences and communities. Surface spills and improper disposal of oil and gas field brine (i.e., salt) and other wastes can impact water from shallow aquifers. Since the State of Indiana does not have a monitoring program for private drinking water wells, little data exists to determine whether private residential wells located near drilling and production operations of oil and natural gas wells have been impacted by these operations and have contaminants at levels of health concern.

Extensive oil and gas production has occurred in Posey County, IN, since the 1930's. Many unused or abandoned production wells, disposal wells, tests wells, and bore holes exist in the region and it is not known whether these wells are properly capped and plugged to prevent the stray migration of petroleum and oil field related materials into the environment. The Indiana Department of Natural Resources (IDNR) continues to evaluate petroleum production wells in the area that were plugged in the past to assess whether proper closure protocols were followed.

ATSDR has been informed by the IDEM that oil fields in this region are periodically pressurized (water flooded) to facilitate and enhance petroleum production. In addition, some areas in Posey County undergo direct injection of natural gas into the subsurface within favorable geologic formation for the purpose of storing it for future use. These activities may result in petroleum-related products migrating into area aquifers.

In 2008, IDEM received complaints from residents of possible petroleum and oil field brine (i.e., salt) contamination in private drinking water wells. In January 2010, IDEM collected water samples from ten private/residential drinking water wells in Posey County, near the City of Mount Vernon. Sampling identified eight wells contaminated with Total Petroleum Hydrocarbons (TPH). The highest detection of TPH was 2,300 micrograms per liter (µg/L), which exceeds the 260 µg/L state residential water criteria. Chloride concentrations that exceed the 250 mg/L Secondary Maximum Contaminant Level (SMCL) were also reported in three of ten wells (IDEM, 2010). In addition, petroleum sheen was observed on one residential well; crude oil was observed inside the well casing of another.

IDEM presented these analytical findings to ATSDR and requested assistance in evaluating potential private well water contamination and possible health implications in the Posey County area. ATSDR agreed to assist IDEM by performing an EI to assess the public health implications of area groundwater contamination.

Methods

Exposure Investigation Design

The EI methodology included identifying participants, administering a questionnaire, sampling their private well water, and analyzing the water for a list of contaminants associated with petroleum production activities. The EI protocol is provided in Appendix B.

Agency Roles

The ATSDR collaborated with IDEM, PCDOH and the United States Geological Society (USGS) during field activities. The specific roles of the partners are provided in Table 1.

Table 1: Agency Roles and Responsibilities		
Activity	***Agency***	***Additional Information***
Developed EI Protocol	ATSDR, USGS, IDEM, US EPA Region 5	All agencies provided input on the Protocol which included the Fact Sheet, Questionnaire, Consent Forms and Sampling and Analysis Plan

Table 1: Agency Roles and Responsibilities		
Activity	***Agency***	***Additional Information***
Identification of Participants	ATSDR, USGS, IDEM, IDNR, PCDOH	• ATSDR compiled area maps using data provided by USGS, IDEM and IDNR to identify potential participants for the EI • USGS recommended participants based on hydrogeological assessment of the area • IDEM provided information on participants included in the 2010 round of sampling • IDNR provided information on oil and gas wells located in the area • PCDOH provided outreach to the community during recruitment and after the sampling
Collection of Water Samples	ATSDR, USGS, IDEM	• ATSDR, USGS and IDEM performed water sampling at participants' homes • USGS coordinated analysis of water samples with the USGS National Water Quality Laboratory
Preparation of Results Letters to Participants and Exposure Investigation Report	ATSDR	• ATSDR prepared letters for participants that provided the results of the methane and non-methane well water sampling

Table 1: Agency Roles and Responsibilities		
Activity	***Agency***	***Additional Information***
		• ATSDR continued to communicate with the partners during the preparation of the EI report

ATSDR Agency for Toxic Substances and Disease Registry
USGS United States Geological Society
IDEM Indiana Department of Environmental Management
IDNR Indiana Department of Natural Resources
USEPA United States Environmental Protection Agency
PCDOH Posey County Department of Health

Private Wells Sampled

The EI was conducted in Posey County, IN, to the northwest of the City of Mount Vernon. Figure 1 in Appendix A includes a map of the area where the EI was conducted. All EI participants were located in the area of, or in close proximity to, the estimated boundaries of the Mount Vernon Consolidated Oil Field.

The USGS and IDEM assisted ATSDR in identifying wells to be sampled. The USGS compiled and interpreted public records and scientific information regarding bedrock geology and groundwater for a study area in the vicinity of Mt. Vernon area of Posey County, Indiana. These records and information were state electronic data, paper files, and literature that included: lithologic logs from oil and gas exploration and production, underground injection, and drinking water well construction; bore hole geophysical logs; aquifer tests; groundwater analysis; and references about bedrock geology and geomorphology. Technical personnel in the IDEM and the Indiana Department of Natural Resources (IDNR) were consulted for sources of information. The USGS interpreted the depth, thickness, areal extent, flow conditions, and uses of freshwater aquifers in the study area and identified potential relations to bore holes, wells, and activities that could allow petroleum and oil field brine to contaminate freshwater aquifers in the investigation area.

USGS evaluated available hydrogeological information to identify participants most likely to be impacted by oil and gas production in the area. In addition to the hydrogeological criteria from public records and scientific information described above, the private wells of interest were identified by evaluating the depth of the well, the location of the well in relation to oil and gas production activities, and whether community complaints are associated with any wells in the area. All candidates resided in the area of or in close proximity to the estimated boundaries of the Mount Vernon Consolidated Oil Field (Figure 1 in Appendix A).

In May 2012, ATSDR, USGS and IDEM met with identified candidates. The ten participants from the 2010 IDEM sampling effort were given the opportunity to be included in the EI; eight agreed to be included. Twenty-two additional residents volunteered to participate. Given the selection process, the test results from this investigation are specific to these participants and are not generalizable to the community-at-large or to other populations.

Environmental Sampling Procedures

Questionairre

As part of the water sampling effort, participants answered a brief questionnaire about water quality in the home and basic demographic information. The questionnaire was administered under OMB # 0923-0040. The questionnaire took approximately 20 minutes to administer (see the EI protocol in Appendix B).

Questionnaire responses were entered directly into a password protected computer using Rapid Data Collector version 2.1 software. Only ATSDR personnel entered data and have access to the computer. Information collected from the questionnaire was used for interpreting analytical results and for explaining the results to individual participants. The water use habits of each participant and the amount and quality of filtering systems, if any, may impact the potential for exposure to identified contaminants. Information on characteristics found on a participant’s property that might impact water quality (e.g., septic tanks, oil wells, etc.) was also obtained. Demographic information was used to qualitatively describe the EI participants. In addition, the question about length of residence at the current address defined the potential duration of exposure for each resident.

Private Well Sampling

Private well water sampling was completed in accordance with the EI field sampling plan (EI protocol, Appendix B). The EI protocol includes information on equipment calibration, sample collection, field sampling and chain of custody. A consent form that was signed by each participant prior to sampling is also included in the EI protocol.

Two sampling teams were used for the EI, each consisting of personnel from ATSDR, USGS and IDEM. The Posey County Department of Health (PCDOH) also supported the sampling effort. USGS provided all field sampling equipment. The teams were instructed on sampling procedures and questionnaire administration prior to the sampling effort to ensure consistency between the teams.

Water sampling was completed at a raw water tap at a location prior to any treatment system. The intent of the EI was to test water that has not been treated to allow an analysis of groundwater coming from the aquifer.

Water Analysis Procedures

A panel of water contaminants potentially associated with water quality and crude oil/ natural gas production was developed by ATSDR in collaboration with IDEM and USGS. It was determined that all 30 wells would be evaluated for water quality parameters, including field measurements for water quality characteristics. The following water quality parameters were evaluated in the field during the sampling effort:

- pH
- Temperature
- Specific Conductance
- Dissolved Oxygen
- Total Dissolved Solids (TDS)
- Turbidity

Laboratory analysis was completed for the following parameters for all 30 wells (see Appendix C):

- Major ions;
- Elements (filtered samples);
- Volatile organic compounds (VOCs); and
- Alpha and beta radiation.

In addition, samples from 10 of the 30 wells were further analyzed for contaminants associated with petroleum production. The 10 sample locations (private wells) were identified in the field based on the presence of a petroleum or other strong odor and/or the presence of bubbly conditions in the water (indicating the presence of natural gases in the water). The location of the private well was also considered to ensure that samples were obtained throughout the investigation area. The following were analyzed:

- To evaluate the presence of petroleum (crude oil):

- Polycyclic Aromatic Hydrocarbons (PAHs),
    - Total Petroleum Hydrocarbons (TPH) (in the diesel range and motor oil range),
    - Oil and Grease indicators (hexane extractable),
    - petroleum hydrocarbons (hexane extractable), and
    - BTEX (benzene, toluene, ethylbenzene, xylene) (analyzed in all 30 homes).
- Natural gases, including methane, ethane, ethene, and propane.

Laboratory Analytic Procedures

The EI protocol provides the details of the analytical procedures and quality assurance/quality control (QA/QC) used in evaluating the groundwater sampling data for the EI (Appendix B).

Approved methods for drinking water analysis were used to evaluate the data and the data were reported to ATSDR electronically through the USGS National Water Information System (NWIS). Filtered samples were used to evaluate elements to ensure that the results reflect dissolved elements and not elements suspended in water.

Results

The results for each well were provided to the individual participants in two parts.

1. The methane sampling results and interpretation were provided in a letter in November, 2012 to the ten participants whose wells were sampled for methane. The remaining 20 participants also received a letter indicating that methane had been reported in wells in the area and provided recommendations to address methane in water.

2. The remainder of the sampling results (e.g., water quality parameters, major ions, elements, VOCs, PAHs, radiation and petroleum-related contaminants) were provided and interpreted in a letter to all participants in February, 2016.

The results of the private well water sampling are evaluated in this EI report for potential health impacts for people drinking the water. The results reflect conditions in the well on the day it was sampled and may fluctutate over time. This Results section provides:

- Demographic Information and Water Use: Demographic information about the participants (information on the characteristics of the people living in the area).

- Data Comparison and Evaluation: Information regarding comparison levels used to evaluate the results of the sampling for each contaminant is provided. The data comparison resulted in the identification of Contaminants of Concern (COCs) that were evaluated to determine whether a health risk may be associated with drinking the water.

Demographic Information and Water Use

Area Demographic Information

The demographics in the Posey County area based on the 2010 US Census are provided in Figure 2 of Appendix A. Demographics are statistics associated with a given population, such as the number of people in an area (population density) and the number of people in the area by race and age.

In 2010, the study area was characterized by a population of 315 homes with 845 people living in the homes. Of the 845 people, 53 were preschool children (6%), 131 people were adults above 65 years old (16%), and 134 were females between 15 and 44 years old (child bearing years) (16%). The majority of the population (97%) in 2010 was white.

The EI conducted in 2012 evaluated 30 homes containing 79 people; all of the participants were white. The participants included 8 children younger than 6 years old (8%), 8 adults older than 65 years (8%) and 10 women of child bearing age (15 to 44 years) (13%). Participants in 21 of the homes reported they had lived in the home more than 10 years; one participant reported living there less than one year.

Private Well Water Use by Participants

Of the 30 participants, 29 used their well water as their primary source of household water. One of the participants requested that their non-drinking water well be sampled instead of their drinking water well. Therefore, the sampling results for this location are not included in the EI analysis but the participant received the results of their well testing by mail.

Information regarding the use of private well water by the 29 participants is provided in Table 2. In addition to well water, some residents used bottled water and public water brought into the home for drinking and cooking. All residents used well water for washing (e.g., bathing, dishes, laundry).

Table 2: Private Well Water Use by Participants			
Household Water Use (29 homes total)	***Well Water Only***	***Bottled Water***	***Public Water Brought Into the Home***
Drinking Water	11 homes	8 homes (bottled only); 6 homes (bottled and well water)	1 home (public water only); 3 homes (public water and well water)
Cooking	26 homes	2 homes	1 home
Washing (bathing, dishes, laundry)	29 homes	none	none

Private Well and Well Water Characteristics

Characteristics of participants' wells were obtained from interviews with participants, observations made during the sampling, and results of the sampling. These characteristics are provided in Table 3. Information provided by the participants includes depth of their private well, characteristics of the well water (bubbly water, taste and odor issues) and the presence of filtration or treatment systems in their home. Sampled characteristics include the presence of total dissolved solids (TDS analyzed in the laboratory) and pH (tested in the field and in the laboratory).

Table 3: Private Well Water Characteristics						
Well Identification	***Depth (ft)***	***TDS (mg/L)***	***pH (field/ laboratory)***	***Bubbly Water[1]***	***Odor/Taste/ Other Issues[1]***	***Filtration System***
PCEI-01	177	***684***[3]	7.47/7.6	S	Sulfur smell/	Sed

Table 3: Private Well Water Characteristics						
Well Identification	***Depth (ft)***	***TDS (mg/L)***	***pH (field/ laboratory)***	***Bubbly Water[1]***	***Odor/Taste/ Other Issues[1]***	***Filtration System***
					"off" smell	
PCEI-02	135 (est)	***522***[3]	6.74/7.1	NR	Sulfur smell/Iron staining	FF, WS
PCEI-03[2]	240 (est)	***1,240***[3]	7.33/7.6	NR	Iron staining	Sed, WS
PCEI-04[2]	Unknown	***602***[3]	8.17/8.2	P and S	Bad odor/ mineral taste/water "feels" different	FF
PCEI-05[2]	175 (est)	***682***[3]	***8.41/8.5***[3]	S	Petroleum smell (P and S)/ laundry smells like petroleum	None
PCEI-07	32	***1,750***[3]	6.62/7.1	NR	No	Sand, UV, Sed, WS
PCEI-08	180	***816***[3]	***8.43/8.5***[3]	P and S	No	IR, Sed, RO
PCEI-09	290 (est)	***510***[3]	7.63/7.9	S	Sulfur smell associated with heavy rain	None

Table 3: Private Well Water Characteristics						
Well Identification	***Depth (ft)***	***TDS (mg/L)***	***pH (field/ laboratory)***	***Bubbly Water[1]***	***Odor/Taste/ Other Issues[1]***	***Filtration System***
PCEI-10[2]	170	***564[3]***	8.19/8.2	S	Petroleum smell (S)	None
PCEI-11	200 (est)	***540[3]***	8.18/8	S	Petroleum smell (S)	Sed
PCEI-12	60	481	6.74/7.1	NR	Water has iron	Sed, WS
PCEI-13[2]	150 (est)	479	7.68/7.9	S	NR	CW
PCEI-14[2]	80 (est)	***609[3]***	7.79/8	NR	Water smells like "sewer" or "dirt"/ worse when not used in a while/ runs out easily	None
PCEI-15	130 (est)	***828[3]***	***8.84/8.9[3]***	S	Petroleum smell (S), salty taste	CF
PCEI-16	100 (est)	448	6.92/7.3	NR	NR	WS
PCEI-17[2]	Unknown	457	6.94/7.4	NR	Petroleum smell (S)/ Garbage smell and taste/ orange color around faucets	CW

Table 3: Private Well Water Characteristics						
Well Identification	***Depth (ft)***	***TDS (mg/L)***	***pH (field/ laboratory)***	***Bubbly Water[1]***	***Odor/Taste/ Other Issues[1]***	***Filtration System***
PCEI-19[2]	217	***1,720[3]***	***8.37/8.5[3]***	S	Salty taste/ runs dry in 15 minutes	CF
PCEI-20	140	***584[3]***	7.82/8.1	NR	NR	FF, Sed
PCEI-22	210	***570[3]***	7.76/8	S	NR	UV, CF, Sed, WS
PCEI-23	300 (est)	***997[3]***	8.07/8.2	NR	NR	None
PCEI-24	140	***1,290[3]***	6.93/7.2	NR	NR	Sed, WS
PCEI-25	62 (est)	***600[3]***	6.85/7.2	NR	"sour smell"	WS
PCEI-26	105	***532[3]***	6.73/7.1	NR	Sweet odor	FF, WS
PCEI-27[2]	180	***1,640[3]***	8.15/8.3	S	Salty taste	Sed, WS
PCEI-28	Unknown	426	6.88/7.2	NR	Sulfur smell when heated	WS
PCEI-29	220	***786[3]***	8.05/8.2	S	Petroleum smell (S)/ don't like the taste of the water	None
PCEI-30[2]	180 (est)	***564[3]***	7.6/7.8	NR	Smells and	None

Table 3: Private Well Water Characteristics						
Well Identification	***Depth (ft)***	***TDS (mg/L)***	***pH (field/ laboratory)***	***Bubbly Water[1]***	***Odor/Taste/ Other Issues[1]***	***Filtration System***
					tastes like sulfur and petroleum (P and S)/ past residents reported bad taste and smell	
PCEI-31	65 (est)	***500[3]***	6.84/7.2	NR	NR	None
PCEI-34	280 (est)	***660[3]***	***8.83/8.8[3]***	NR	Oily/slimy water	CF, Sed

PCEI Posey County Exposure Investigation sampling location
NR Not Reported
mg/L milligrams per liter of water
TDS total dissolved solids
Est estimated depth of well

[1] P and S – used to indicate whether the presence of bubbles and/or a petroleum smell were identified by the participant (P) or by the EI team during the sampling (S)

[2] The bolded well identification indicates that this was one of the ten wells sampled for petroleum-related constituents

[3] The bold/italics value indicates that the Secondary Maximum Contaminant Level (SMCL) was met or exceeded for TDS (500 mg/L) and pH (6.5<pH<8.5).

<u>Treatment Systems</u>

CF = charcoal filter
FF = faucet filter
IR = iron removal system
RO = reverse osmosis
Sand = sand filter
Sed = sediment filter
UV = ultra violet system
WS = water softener
CW = whole house carbon wrap (filters out chlorine, sand, silt, rust and sediment)

Many of the participants were aware of the depth of their private well. The depth of the wells tested ranged from shallow (32 to 60 feet deep) to deep (up to approximately 300 feet deep).

General laboratory indicators of water quality include total dissolved solids (TDS) and pH. A discussion of the comparison levels used to evaluate TDS and pH is provided below (Data Comparison and Evaluation). All of the well water tested as part of the EI either exceeded or approached the comparison level for TDS. Similarly, several wells had pH levels that were above or approaching the comparison level for pH. These exceedences and near exceedences indicate that the water in the Posey County area is generally not suitable for drinking and cooking (see discussion below).

Many participants indicated that their well water had a bad taste or smell (Table 3). The main complaints included a sulfur smell, salty taste and staining of plumbing fixtures. Several homes reported a petroleum smell to the water as well. Of the 29 participants, 20 had water treatment systems ranging from simple filters located on their faucets to whole-house treatment systems. The most common whole house treatment systems included sediment filters, charcoal filters, and water softeners. Participants often reported issues associated with a bad taste or smell regardless of whether they had treatment systems installed in their homes (Table 3).

The presence of bubbles in the water was noted during the water sampling by the EI team. The presence of bubbles was used as an indicator that gases, primarily methane, may be present in the water. As discussed below, the presence of bubbly water and a petroleum or other strong smell were used by the sampling team as an indicator to test the water should be sampled for petroleum-related constituents.

Data Comparison and Evaluation

Water sampling results were compared to appropriate comparison levels, including ATSDR comparison values (CV) to identify contaminants of concern (COCs). Comparison levels from other federal and state agencies (Department of Interior, Indiana Department of Environmental Management) and the World Health Organization (WHO) were used, as appropriate.[1] If a contaminant is found at a level below the comparison level, harmful effects are unlikely to occur. If a contaminant is found at a level above the comparison level, it is further evaluated to determine if exposure may result in health effects. A list of appropriate comparison levels and the results of the comparison are provided in Appendix C; COCs are listed in Table 4.

1Values not formerly reviewed or endorsed by ATSDR.

Table 4: Identification of Contaminants of Concern (COCs)				
Contaminant	***Maximum in Well Water***	***Frequency of Detection***	***Comparison Level***	***Exceedences/ Number of Detections***
Water Quality Indicators				
pH	pH of 8.84 (in field) to 8.9 (in laboratory)	measured in all samples	6.5-8.5 (SMCL[1]: low pH – bitter metallic taste and corrosion; high pH – slippery feel, soda taste, deposits)	2/29 were above a pH of 8.5
Major Ions (mg/L)				
Total Dissolved Solids (TDS)	1,750	measured in all samples	500 (SMCL[1] – colored water and staining, salty taste, hardness)	24/29
Sodium	680	29/29	20 (EPA – for salt-sensitive people)	26/29
Chloride	705	29/29	250 (SMCL[1] – salty taste)	5/29
Elements (µg/L)[2]				
Iron	1,400	29/29	300 (SMCL[1] – rusty color, metallic taste and red-orange staining)	9/29
Lithium	56.3	29/29	31 (RSL)	4/29
Manganese	803	29/29	500/1,800 (Child/Adult RMEG)/50 (SMCL[1] – black staining; bitter, metallic taste)	2/29 (RMEG); 5/29 (SMCL)
Arsenic	8	23/29	0.02 (CREG), 3/11 (Child/Adult Chronic EMEG)/10 (MCL)	23/23 (CREG); 0/23 (MCL)

Table 4: Identification of Contaminants of Concern (COCs)				
Contaminant	***Maximum in Well Water***	***Frequency of Detection***	***Comparison Level***	***Exceedences/ Number of Detections***
Uranium	10	16/29	2/7 (Child/Adult Intermediate EMEG)/30 (MCL)	5/16 (EMEG); 0/16 (MCL)
Radiation (pCi/L)				
Alpha radiation, 30 day recount	15	26/26[3]	15 (MCL)	1/26
Alpha radiation, 3 day count	31.6	25/26[3]	15 (MCL)	3/25
Total Petroleum Hydrocarbon (TPH)/oil and grease/gases				
Total Petroleum Hydrocarbons (TPH) (Sum of DRO and MRO compounds) (µg/L)	1100	8/10	260 (IDEM RISC)	7/8
Methane (mg/L)	24	10/10	10 (Action Level - DOI)	6/10

mg/L milligrams per liter of water
µg/L micrograms per liter of water
pCi/L picocuries per liter of water
NA comparison level not available
MCL Maximum Contaminant Level (EPA value)
SMCL Secondary Maximum Contaminant Level (EPA value)
IDEM RISC Indiana Department of Environmental Management – Risk Integrated System of Closure
EMEG Environmental Media Evaluation Guide (ATSDR value)
RSL Regional Screening Level (EPA value)
RMEG Reference Dose Media Evaluation Guide (ATSDR value)
CREG Cancer Risk Evaluation Guide (ATSDR value)
DOI US Department of the Interior (DOI, 2001) (Action Level – Warning Should be Given to Resident)
DRO Diesel Range Organic Compounds
MRO Motor Range Organic Compounds

[1] Basis for SMCL values provided in http://water.epa.gov/drink/contaminants/secondarystandards.cfm[2] All element analyses reflect filtered samples.

[2]Samples were not analyzed for radiation in three locations, therefore, the total number of sampled locations was 26.

The next step in the health evaluation is to evaluate the potential health impact of the COCs present in the water. The evaluation includes identifying appropriate receptors (i.e., people who are exposed) and routes of exposure (e.g., ingestion of water) and determining whether the amount of exposure is a possible health concern.

Identification of Receptors and Routes of Exposure

The evaluation of COCs begins with the determination of who may be exposed (i.e., receptors), and how they may be exposed. We assumed that the participants who use private well water as their drinking water are exposed to contaminants through ingestion (i.e., drinking). We assumed that ingestion of groundwater will be the primary route of exposure for the identified COCs (elements, ions, TPH, radiation and methane). Given that most participants reported being long-term residents, chronic exposure (greater than 1 year) was evaluated. The inhalation and dermal pathways of exposure were not considered to be primary routes of exposure for those COCs that could be quantitatively evaluated. Although alpha radiation was identified as a COC, it cannot be quantitatively evaluated since it is a general indicator of radiation and the specific contaminant associated with the radiation is not known. Similarly, other indicators of water quality (e.g., pH, TOC, TPH) were also identified as COCs in well water in the area, but they cannot be quantitatively evaluated.

Although methane is a gas, the primary hazard associated with exposure is safety since methane gas may accumulate in enclosed places and result in an explosion hazard. At very high concentrations, methane may displace oxygen and become an asphyxiation hazard.

Exposure Dose Calculations and Health Assessment

All COCs were evaluated to determine whether the amount of a contaminant in the drinking water may be of health concern for people that drink the water. The exposure dose is the amount of a contaminant that gets into a person's body. An explanation of how we calculated the estimated exposure doses, the intake factors used, and the results of the analysis are provided in Appendix D and discussed below.

Discussion

Participants were informed of the results of their sampling by personal communication and individuals are not identified in this EI.

Contaminants detected in private well water during the EI are discussed in the following groups:

- Water Quality Indicators

- Salts and Iron
- Elements
- Radiation

Water Quality Indicators

Well water was tested for indicators of water quality, including petroleum-related products, TDS, and pH. TDS and pH were assessed in all 29 wells and petroleum-related products and methane were assessed in 10 of the 29 wells.

The pH of the well water was tested during the sampling as well as in the laboratory. The pH in participants' water ranged from 6.62 to 8.84 during the sampling and 7.1 to 8.9 in the laboratory. At two locations, the pH of the well water was greater than the SMCL range of 6.5 to 8.5 (US EPA, 2013a). Three additional locations had pH level equal to 8.5. Water at a pH greater than 8.5 may have a soda taste, feel slippery, and leave deposits on fixtures (e.g., sink).

TDS in the participants' well water ranged from 426 to 1,750 mg/L with 24 of 29 samples above the US EPA's Secondary Maximum Contaminant Level (SMCL) of 500 mg/L (US EPA, 2013a). The SMCL is based on a salty taste, discoloration of the water and staining. Thus, some well water in the area may taste salty and discolor plumbing fixtures. Similarly, iron and manganese at levels above their SMCL can result in a bad taste to the water as well as staining of fixtures (see the discussions for iron and manganese below).

Petroleum-Related Contaminants

Petroleum products are not normally found in drinking water. Given that the investigation area is located over an oil field, petroleum-related contaminants were sampled during the EI. In addition, gases often associated with petroleum were evaluated in the investigation: methane, ethane and ethane.

As mentioned previously, 10 of the 29 homes in the EI were tested for petroleum-related contaminants. The homes were chosen for the petroleum-related sampling based on the appearance of bubbles in the water (an indicator of gas in the water) or if the water had a petroleum smell or other strong odor. Although more than ten homes met these criteria, per the protocol (Appendix B), only ten homes were sampled. Final selection of homes to be tested ensured that sampling locations were spread across the investigation area.

For this investigation, the presence of petroleum (i.e., crude oil) was evaluated using various parameters including:

- Polycyclic aromatic hydrocarbons (PAHs) – this analysis included all PAHs, which may be associated with petroleum.

- Total petroleum hydrocarbons (TPH) – TPH was assessed by evaluating motor oil range (MRO) and diesel oil range (DRO) organic compounds. MRO and DRO are expected to be associated with crude oil. Gasoline range organics (GRO) were not assessed because it is a refined oil that is not naturally occurring and, therefore, is not expected to be found in groundwater.

- "Oil and Grease" - this analysis assessed the amount of oil and grease in hexane-extractable material

- Petroleum hydrocarbons – this analysis assessed the amount of total recoverable petroleum hydrocarbons in hexane-extractable material

- Volatile organic compounds (VOCs) – this analysis included BTEX (benzene, toluene, ethylbenzene, and xylene), which are associated with petroleum. (BTEX were analyzed in all 29 wells sampled).

Analysis of these five parameters are expected to indicate crude oil in various stages of biodegradation, miscibility, and solubility in water. Detectable concentrations of constituents were reported for TPH, and 'Oil and Grease' (see discussion below). BTEX were tested for in all 29 wells and were not detected in any of the ten wells that were sampled for petroleum-related contaminants. Low levels were detected in several of the remaining 19 wells.

In addition to the evaluation for petroleum-related contaminants, gases often associated with petroleum were assessed in the investigation: methane, ethane and ethene.

Table 5 provides further information regarding well depth and petroleum-related contaminant results. The depth of the wells tested for petroleum products ranged from 80 to 240 feet below ground surface with two well depths unknown. Half of the well depths were estimated by the homeowners.

Table 5: Petroleum-Related Contaminants[1]					
Location	***Well Depth (ft)***	***TPH (µg/L)***	***Oil and Grease (mg/L)***	***Methane (mg/L)***	***Ethane (µg/L)***
PCEI-03	240 (est)	940	2.6 (est)	10 (est)	0.8
PCEI-04	Unknown	704	3.7 (est)	24 (est)	1.3
PCEI-05	175 (est)	790	4.5 (est)	15 (est)	1.1
PCEI-10	170	520	3.4 (est)	11 (est)	0.4 (est)
PCEI-13	150 (est)	281	3.3 (est)	8.8 (est)	0.3 (est)
PCEI-14	80 (est)	285	2.3 (est)	9.3 (est)	1.3
PCEI-17	Unknown	ND	2.5 (est)	0.0032	ND
PCEI-19	217	40	2.6 (est)	15 (est)	0.9
PCEI-27	180	ND	2.2 (est)	8.9 (est)	9.1 (est)
PCEI-30	180 (est)	1,100	4.3 (est)	10 (est)	1.2

[1] PAHs, BTEX, petroleum hydrocarbons and ethene were not detected in any well water sample.

ft feet
µg/L micrograms per liter of water
mg/L milligrams per liter of water
est estimated value because the level of these contaminants was high and exceeded the method parameters
ND Not Detected in the sample

Petroleum contamination in water is often measured as TPH, which is a mixture of many chemicals. In this EI, TPH was assessed as the sum of DRO and MRO and compared to the IDEM comparison level of 260 micrograms per liter (µg/L) for TPH (IDEM, 2001[2]). The comparison level is a non-specific level that represents exposure to organics in the diesel range (DRO) and the motor oil range (MRO). Water containing TPH will generally have an unpleasant taste and smell.

In participants' well water, TPH ranged from not being detected to 1,100 µg/L with 7 of 10 samples being above the comparison level of 260 µg/L (Table 5). Potential health effects associated with TPH are not known because it is a generalized measurement used to screen for petroleum contamination and the specific chemical make-up of the TPH is not known.

The presence of miscible crude oil (i.e., oil that is suspended in water, but not dissolved) was also evaluated using two extraction techniques using hexane ('Oil and Grease' parameter and 'petroleum hydrocarbon' parameter). 'Oil and Grease' was found in the ten tested wells at estimated concentrations ranging from 2.2 to 4.5 mg/L ('Oil and Grease' does not have a comparison level). 'Petroleum hydrocarbons' were not detected in any of the ten water samples, indicating that crude oil was not detected using this extraction method.

PAHs were not detected in the ten water samples at the site. Four organic compounds associated with petroleum products (benzene, toluene, ethylbenzene and xylene (BTEX)) were tested in all 29 wells. BTEX was not detected in any of the ten wells that were tested for petroleum-related contaminants. In the remaining 19 private wells, benzene, ethylbenzene and toluene were each found in one well, and xylene was found in two wells. All the detections were at levels far below their comparison levels (Appendix C).

Based on the methods used and the reported results, there is evidence that dissolved and degraded miscible petroleum was found in many of the well water samples in the investigation area.

Methane Gas

Methane is a colorless, odorless gas that can dissolve in water. Safety is the main concern for high levels of methane because it is a fire and explosive hazard. If present, methane is released from water into the air during everyday household activities. If methane gas builds up to a high enough level in an enclosed space that is not well ventilated, a spark or ignition source can cause a fire or explosion. Activities which use a large volume of water in a small or poorly ventilated area can also cause methane gas to build up. Examples of such activities include running a dishwasher or a washing machine and showering.

2Values not formerly reviewed or endorsed by ATSDR.

Methane gas that builds up in an enclosed space can also take the place of oxygen in the room and the lack of oxygen may make it difficult to breathe. This would only happen with a very high buildup of methane in an unventilated room. There is insufficient toxicological information available to determine whether there may be health effects from drinking water that contains methane or other similar dissolved gases. However, because methane in water evaporates quickly, it is usually not considered to a health concern for consumption.

Action levels for methane in water are taken from the US Department of the Interior (US DOI) guidance on methane hazards (US DOI, 2001). Methane detected at a concentration below 10 mg/L does not warrant immediate action except for monitoring the appearance of the water and possibly ventilating the home. Concentrations from 10 mg/L through 28 mg/L are considered to be at a warning level. At this level, additional recommendations include the installation of a combustible gas monitor, ventilation of the home, ventilation of the well head, and removal of ignition sources in enclosed areas of the home. Concentrations above 28 mg/L require immediate action, and immediate ventilation of the wellhead is recommended. At this level, treatment of the water to remove methane is needed to reduce immediate safety risks.

In the 10 water wells tested, methane ranged from 0.0032 to 24 mg/L (Table 5). Test results found one of the samples in the very low range (0.0032 mg/L) and the remaining nine samples approaching or exceeding the warning level of 10 mg/L (8.8 to 24 mg/L). None of the samples exceeded the immediate action level of 28 mg/L.

Participants were notified of their methane results and provided with recommendations that included increasing ventilation in areas of potential gas accumulation and installing gas monitors that would notify the resident if gas levels reached an unsafe level in the air. All participants, including those whose wells were sampled for methane and those that were not, were notified of the potential methane issue. IDEM provides a fact sheet for methane gas in drinking water at http://www.in.gov/dnr/dnroil/5533.htm (tap on the Methane Gas & Your Water Well link).

Other gases, ethane and ethene, were also sampled in the well water from the ten homes. Ethene gas was not detected in any of the tested samples, but ethane gas was found in 9 of 10 water samples at levels ranging from not being detected to 9.1 µg/L (Table 5). A comparison level is not available to assess ethane gas, but it is found in natural gas and is a byproduct of petroleum refining.

Salts and Iron

Tolerable Upper Limits (ULs) (IOM, 2010) are provided below in the discussion for salts and iron. A UL is the highest level of a chemical that can be consumed daily that is unlikely to be harmful for healthy people.

Sodium and Chloride

Sodium and chloride are essential nutrients that are used in the body for proper muscle and nerve function. Sodium and chloride are found together in the form of salt. Some people with medical conditions such as high blood pressure and kidney problems may be on salt-restricted diets.

In participants' well water, sodium ranged from 17 to 680 mg/L with 26 of 29 samples above the US EPA comparison level of 20 mg/L for people on a sodium-restricted diet (US EPA, 2003). The ULs for sodium are 1,500 mg/day for children and 2,300 mg/day for adults (IOM, 2005; IOM, 2010). Drinking the maximum concentration of 680 mg/L of sodium each day would result in an intake of about 60 percent of the UL for an adult and 45 percent for a child.

Chloride levels ranged from 2 to 705 mg/L with 5 of 29 samples above the US EPA's SMCL of 250 mg/L (US EPA, 2013a). The SMCL is not considered to be harmful to health but is based on a salty taste. Thus, well water may taste salty. The ULs for chloride are 2,300 mg/day for children and 3,600 mg/day for adults (IOM, 2010). Drinking the maximum concentration of 705 mg/L of chloride each day would result in an intake of about 40 percent of the UL for an adult and about 30 percent for a child.

Since most salt intake is through the diet, residents in the area may want to closely monitor the amount of salt in their diet if their well water tastes salty, especially if they are on a salt-restricted diet.

Iron

Iron is an essential nutrient that helps carry oxygen in the blood. Low iron in the body can result in anemia. Having too little iron in the diet is generally considered a bigger problem than having too much. Some people, however, have a genetic condition called hemochromatosis where their body absorbs too much iron resulting in a build-up of iron in the body that can result in organ damage (CDC, 2014). CDC estimates that 1 to 6% of the population has hemochromatosis. People with this condition may be on a low-iron diet.

Iron is found naturally in soil and water. Too much iron can give water a brownish color and can leave red or orange rust stains on the sink, toilet, bathtub or shower surfaces. Water with high levels of iron can also stain clothes and dishes when washing.

Iron levels ranged from 6.1 to 1,400 µg/L; 9 of 29 samples were above the US EPA's SMCL of 300 µg/L (US EPA, 2013a). The SMCL is not a health-based value but is based on a metallic taste and staining of plumbing fixtures. Drinking the maximum concentration of 1,400 µg/L of iron each day would result in an intake of about 5 percent of the UL for an adult and 4 percent for a child. The ULs for iron are 40,000 µg/day for children and 45,000 µg/day for adults (IOM, 2010). The majority of iron intake is from the diet.

The amount of iron in participants' well water is not likely to cause health effects, unless the participant is on an iron-restricted diet, but the water may have a metallic taste and may stain plumbing fixtures.

Elements

Arsenic

Arsenic is a naturally occurring element that is found in soil and water. Because of area geology, many communities may have private wells with naturally-occurring arsenic in the water. Levels of naturally-occurring arsenic in groundwater in the North Central portion of the United States range from less than 1 µg/L to 20 µg/L (ATSDR, 2007). Other sources have reported a range of arsenic in groundwater in the United States of 8 to 13.9 µg/L (US EPA, 2004). In the past, naturally-occurring arsenic has been detected in private wells located to the east of the investigation area in Mount Vernon, IN, at levels ranging from 13 to 77 µg/L (Ross, 2010).

In participants' well water, arsenic ranged from below detection (<0.03 µg/L) to 8 µg/L with 23 of the 30 samples having levels greater than the detection limit of 0.03 µg/L. All of the samples with detected values exceeded the cancer comparison level of 0.023 µg/L. The cancer comparison level represents an increase in the incidence of skin cancer of one in one-million in addition to a person's natural background lifetime risk of approximately 1 in 2 for men and 1 in 3 for women (American Cancer Society, 2013). Levels below the detection limit of 0.03 µg/L may be above the cancer comparison level of 0.023 µg/L.

All of the detected values exceeded the cancer comparison level of 0.023 µg/L. In addition, one result (8 µg/L) exceeded the ATSDR noncancer comparison level for children (3 µg/L) based on effects on the skin (ATSDR, 2007). The other 22 detected values ranged from 0.03 to 1 µg/L. Because ATSDR's comparison levels are exceeded, additional evaluation is required to determine whether harmful effects might be possible.

ATSDR used health-based guidelines to further assess both noncancer and cancer effects for arsenic. For noncancer effects, ATSDR used its Minimal Risk Level (MRL) (0.0003 mg/kg/day). The MRL is based on a study that found skin lesions in people exposed to various levels of arsenic in their drinking water over a long period of time (ATSDR, 2007). The no-observed-adverse-effect-level (NOAEL) of 0.0008 mg/kg/day was used as the basis for the MRL (this value was divided by a factor of 3 to reflect human variability to obtain the MRL of 0.0003 mg/kg/day). Hyperpigmentation (skin discoloration) and keratosis (rough skin) were found at a dose of 0.014 mg/kg/day and more serious dermal lesions were found at doses of 0.038 to 0.065 mg/kg/day. These effects were seen following several decades of exposure.

To assess noncancer effects of arsenic, an exposure dose (the amount of contaminant that a person is exposed to daily) was calculated for an infant aged birth to < 1 year old, which reflects the most highly exposed receptor. The concentration of 8 µg/L is equivalent to a daily exposure dose of 0.0011 mg/kg/day for the infant. The calculated dose is divided by the MRL to derive a Hazard Quotient (HQ) (Appendix D). If the HQ is below 1, health effects are not expected to occur. If the HQ is greater than 1, the COC is further evaluated using toxicity information for the chemical provided in the scientific literature.

For the infant, an HQ of 4 was derived (Appendix D). HQs for older children (2 to 21 years old) ranged from 0.9 to 2 (doses of 0.0003 to 0.0006 mg/kg/day). The HQ for an adult was 1 (dose of 0.0003 mg/kg/day). The skin effects reported in the study were found after several decades of consistent exposure to arsenic in the drinking water. The exposure dose for the infant (0.0011 mg/kg/day) is above the NOAEL of 0.0008 mg/kg/day for long term exposure and the exposure doses for the older children and adults ranged from 0.0003 to 0.0006 mg/kg/day, which are below the NOAEL. The NOAEL is a level where no adverse effects were noted in a long-term (chronic) study in humans.

For cancer, the excess cancer risk for the maximum detected value (8 µg/L) was two in 10,000 (dose of 0.00015 mg/kg/day; Appendix D), which is above US EPA cancer risk target of one in 10,000. This means there may be an additional two cases of cancer in 10,000 people in addition to the background cancer risk of approximately 1 in 2 for men and 1 in 3 for women (American Cancer Society, 2013). This calculated risk assumes daily, long-term exposure to the maximum detected value of 8 µg/L in a person that lives in the same home for 33 years (21 years as a child and 12 years as an adult) (Appendix D). The risk associated with children and adults that drink less well water, supplement their well water intake with bottled water, or live in their homes less than 33 years would be lower.

All of the private wells sampled during this investigation had arsenic levels below the MCL (the regulatory level for public water systems) of 10 µg/L (US EPA, 2013a). The MCL is a regulatory level used for public water systems. The amount of arsenic in public water systems must be below this level. Although the levels of arsenic in all the wells sampled during the EI were below the MCL, drinking water containing levels detected during this investigation may still pose a low health risk over a lifetime of use.

Manganese

Manganese is an essential nutrient that is needed for good health. However, too much manganese in food and water can result in effects on the nervous system. People with liver disease may be more sensitive to the intake of too much manganese (ATSDR, 2012a). Manganese is found naturally in the environment.

In participants' well water, manganese ranged from 0.58 to 803 µg/L with 2 of 29 samples (803 and 517 µg/L) above the comparison level of 500 µg/L for children. The comparison level is based on effects on the nervous system (US EPA, 2013c). An additional three samples (80.8, 101, 172 µg/L) were above the US EPA's SMCL of 50 µg/L (US EPA, 2013a). The secondary MCL is not a health-based value but is based on a metallic taste and staining of plumbing fixtures.

Drinking the maximum concentration of 803 µg/L of manganese each day would result in an intake of about 15 percent of the UL for an adult and 40 percent for a child, although most of the manganese in the typical diet is from foods such as grains, cereals and tea (ATSDR, 2012a). The ULs for manganese are 2,000 µg/day for children and 11,000 µg/day for adults (IOM, 2010).

A health-based guideline is available to further assess the noncancer effects of manganese. A reference dose (RfD) of 0.05 mg/kg/day is available for manganese. The RfD is based on central nervous system effects in a human study (US EPA, 2013c).

To assess noncancer effects of manganese, an exposure dose (the amount of contaminant that a person is exposed to daily) was calculated for an infant aged birth to < 1 year old, which reflects the most highly exposed receptor. The concentration of 803 µg/L is equivalent to a daily exposure dose of 0.11 mg/kg/day for the infant. The calculated dose is divided by the RfD to derive a Hazard Quotient (HQ) (Appendix D). If the HQ is below 1, health effects are not expected to occur. If the HQ is greater than 1, the COC is further evaluated using toxicity information for the chemical provided in the scientific literature.

An HQ of 2 was derived for an infant (Appendix D). HQs for older children (2 to 21 years old) ranged from 0.5 to 1 (doses of 0.03 to 0.06 mg/kg/day). The HQ for adults was 0.6 (dose of 0.03 mg/kg/day).

Given that the HQ indicated that infants may be at risk for harmful effects from manganese in water, ATSDR evaluated several studies done to evaluate potential harmful effects of manganese in children. The studies focused on potential effects of manganese exposure on intellectual impairment. A study by Bouchard *et al.* (2011) reported that higher manganese levels in water were significantly associated with lower IQ (intelligence quotient) scores. Levels in water ranged from 1 to 2,700 µg/L with a median concentration of 34 µg/L. The authors of the study reported a 6 point difference in IQ scores for children in the lowest exposure group (median manganese concentration of 1 µg/L) and children in the highest exposure group (median of 216 µg/L).

Several case reports of manganese exposure in children are available. In one study, a 5-year-old child exposed to 1,700 to 2,400 µg/L in private well water was found to have behavioral and neurological symptoms (Brna *et al.* 2011). Manganese exposure was confirmed by elevated blood and serum manganese levels, although an estimated dose was not provided by the authors. The well was located at a second home and was only used during the summer for several years.

Similarly, Woolf *et al.* (2001) reported a case study of a 10-year-old child exposed for five years to water from a private well contaminated with manganese at 1,200 µg/L. Teachers noticed learning issues in the classroom and a medical evaluation showed problems with verbal and visual memory. ATSDR estimated a dose of 0.06 mg/kg/day from the Woolf *et al.* (2001) study (ATSDR, 2012a). These case reports provide information on potential health effects on individual children exposed to manganese in drinking water. These individual reports are not scientific studies and causality of health effects resulting from manganese exposure cannot be drawn.

Wasserman *et al*. (2006) evaluated intellectual function in 142 children (aged 10 years) where the average drinking water manganese level was 793 µg/L, which is comparable to the maximum detected concentration in this EI (803 µg/L). In this study, children were grouped into four exposure levels (<200 µg/L; 200 to 499 µg/L; 500 to 999 µg/L; and ≥ 1,000 µg/L). Daily dose estimates associated with these concentrations were 0.008, 0.035, 0.062 and 0.14 mg/kg/day. Associations with manganese exposure and intelligence (reduced full-scale, performance, and verbal scores of intelligence) were found in a dose-response fashion (*e.g.*, the higher the dose of manganese, the greater the impact on intelligence).

The highest reported concentration for the sampled wells in this EI was 803 µg/L (dose of 0.1 mg/kg/day for infant). The manganese concentration in several of the wells reported for this EI are comparable to the concentrations cited in the above studies that reported neurological effects in children (216 to 1,200 µg/L). An infant consuming water with manganese at the maximum levels detected in this EI (803 µg/L), such as consuming well water mixed with infant formula, may experience harmful effects (e.g., neurological impacts including not reaching full IQ potential as well as learning and memory problems).

Uranium

Uranium is a naturally occurring element that is found in the environment. Exposure to high amounts of uranium can result in harmful effects on the kidneys (ATSDR, 2013). The uranium detected in well water during the sampling is non-radioactive uranium. Radiation associated with other forms of uranium were not assessed in this EI.

In participants' well water, uranium ranged from not detected to 10 µg/L with 5 of 29 samples above the comparison level of 2 µg/L (range of 3.8 to 10 µg/L). The comparison level is based on effects on the kidneys in children (US EPA, 2013c). In adults, the comparison level is 7 µg/L and was exceeded in 3 of the 29 samples (range of 7.9 to 10 µg/L).

A health-based guideline is available to further assess the noncancer effects of uranium. An RfD (0.003 mg/kg/day) is available for uranium based on effects on body weight and the kidney (US EPA, 2013c).

To assess noncancer effects of uranium, an exposure dose (the amount of contaminant that a person is exposed to daily) was calculated for an infant aged birth to < 1 year old, which reflects the most highly exposed receptor. The concentration of 10 µg/L is equivalent to a daily exposure dose of 0.0014 mg/kg/day for an infant. The calculated dose is divided by the RfD to derive a Hazard Quotient (HQ). If the HQ is below 1, health effects are not expected to occur. If the HQ greater than 1, the COC is further evaluated using toxicity information for the chemical provided in the scientific literature.

For the infant, an HQ of 0.5 was derived (Appendix D). This HQ indicates that exposure to uranium is not expected to cause harmful health effects. In addition, all samples of uranium are below the MCL (the regulatory level for public water systems) of 30 µg/L. ATSDR does not consider uranium in private well water tested to pose a health concern.

Lithium

Lithium is an element found in nature that is not an essential element in the body. Lithium is primarily taken into the body through the diet (grain, vegetables and animals) but some lithium may be found in water (ATSDR, 2012b). Lithium is sometimes given by physicians for medical purposes and can have side effects such as effects on the kidneys, nervous system (tremors, confusion), cardiovascular system, endocrine system and an upset stomach (US EPA, 2008; PDR, 2013). The lowest therapeutic dose associated with lithium treatment in adults is approximately 2 mg/kg/day for an adult (US EPA, 2008).

In participants' well water, lithium ranged from 9.2 to 56.3 µg/L with 4 samples of 29 being above the EPA comparison level of 31 µg/L for children (US EPA, 2013b). An EPA Provisional Peer-Reviewed Toxicology Value (PPRTV) for lithium of 0.002 mg/kg/day is available based on the lower bound of the therapeutic serum lithium concentration range (2 mg/kg/day with an uncertainty factor of 1000 (10 to adjust from a LOAEL to a NOAEL, 10 to protect susceptible individuals and 10 for deficiencies in the database) = 0.002 mg/kg/day) (US EPA, 2008). There is very little toxicological data on lithium exposures in young children because most of the information is available for adults being treated with therapeutic levels of lithium. The potential for adverse health effects in sensitive subpopulations is uncertain because of the lack of relevant study data. Potentially sensitive populations for lithium exposures include patients undergoing lithium treatment, children, and pregnant women. Other sensitive individuals may be those with renal, cardiovascular, neurological and endocrine disease (US EPA 2008) since the literature has reported effects on these organ systems as a result of therapeutic use of lithium in adults.

An exposure dose (the amount of contaminant that a person is exposed to daily) was calculated for an infant aged birth to < 1 year old, which reflects the most highly exposed receptor. The maximum detected value of 56.3 µg/L represents a dose of 0.008 mg/kg/day for an infant (aged birth to < 1 year old) and 0.002 mg/kg/day for adults. The calculated adult dose of 0.002 mg/kg/day is equal to the PPRTV value and is approximately 0.1% of the therapeutic dose (2 mg/kg/day) (PDR, 2013; Baldessarini and Tarazi, 2001).

The health-based guideline was based on side effects associated with therapeutic use of lithium in adults. There is very little toxicological information on the health effects of lithium in children or other sensitive individuals. People who are taking lithium for medical reasons or those with children or other sensitive individuals in the home may want to discuss the issue of lithium in their well water with their physician.

Radiation

Alpha and Beta Radiation

Twenty-six of the wells were tested for two types of radiation, alpha and beta radiation. Radiation is present naturally in the environment. Samples were not obtained at two of the homes because the samples could not be submitted to the laboratory in time to meet method holding times and one of the samples was lost at the laboratory (sample bottle broken) and not analyzed.

When water is tested for radiation, the laboratory tests the same sample after 3 days and again after 30 days to quantify emissions from short lived radionuclides as well as decay products. The alpha and beta radiation tested in well water are a basic measure of radiation. This type of analysis does not indicate what the radionuclides are that may be producing the radiation.

The results of the alpha and beta radiation analyses are presented in Table 6. For alpha radiation, 3 of 26 samples were above the MCL (the regulatory level for public water systems; US EPA, 2013a) for the 3-day analysis and 1/26 samples equaled the MCL for the 30-day analysis. The MCL for alpha radiation is based on an increased cancer risk following exposure to radiation for many years. The amount of beta radiation in participants’ well water was below the MCl for both the 3-day and 30-day analyses.

Table 6: Results of the Alpha and Beta Radiation Analyses

Alpha radiation (pCi/L): MCL = 15 pCi/L		**Beta radiation (pCi/L): MCL = 50 pCi/L**	
3-day	***30-day***	***3 day***	***30 day***
ND – 31.6 (3/26 exceed MCL: PCEI-03, PCEI-07, PCEI-24)	0.7-15 (1/26 equals MCL; PCEI-03)	ND-4.8 (0/26 exceed MCL)	1.3-8.1 (0/26 exceed MCL)

ND = not detected

Although the MCL was exceeded in three of the 26 wells, an increased cancer risk associated with exposure to alpha radiation cannot be assessed because a toxicity factor is not available. Further sampling to evaluate which contaminants may be producing the alpha radiation would be needed to determine the source of the radiation.

Conclusions

Based on the results of the private well sampling, ATSDR concludes that the water in the investigation area may not be suitable for drinking and cooking (SMCL exceedances, presence of TPH and Oil and Grease), may be of health concern for some individuals (elevated concentrations of salts, metals, and radiation) and may be an explosive hazard (methane gas).

ATSDR drew several conclusions regarding the quality of the well water tested during the EI:

- Health-related findings:
  - Methane in well water was elevated in nine of ten of the private wells tested. Safety is the main concern associated with methane gas because it is a fire and explosive hazard. If present, methane can be released from water into the air during everyday household activities. If methane gas builds up to a high enough level in an area that is not well ventilated, a spark or ignition source can cause a fire or explosion. Methane gas that builds up in an enclosed space can also displace of oxygen in the room and the lack of oxygen may make it difficult to breathe. This would only happen with a very high buildup of methane in an unventilated room.

- Salts, iron and lithium were elevated in many of the wells. Elevated levels of these contaminants may be a concern for sensitive individuals (e.g., children, pregnant women) or people on salt- or iron-restricted diets and those who are taking lithium for medical purposes. These contaminants likely are not a health issue for healthy individuals. The salt and iron may also result in water quality/potability issues, including a bad taste and the staining of plumbing fixtures.

- Manganese in two of the 30 wells was found at a level that may be associated with behavioral and neurological effects in infants and children when ingested over several years, based on case reports in the scientific literature. Manganese can also result in a bad taste to the water and the staining of plumbing fixtures.

- Alpha radiation was found in three of 26 wells tested for at concentrations above the comparison level. The measurement of alpha radiation is intended to provide information on the presence of alpha radiation, but does not define the particular radionuclide that may be emitting the alpha radiation. Beta radiation levels were found below the comparison level in all tested wells. Radiation exposure is associated with an increased risk of cancer over a lifetime.

- Arsenic was found in some private wells at levels below EPA's Maximum Contaminant Level (MCL) (the regulatory level for public water systems) but above ATSDR's long-term, health-based comparison level. Although the levels in the wells were found below the MCL, drinking water with these levels may still pose a low health risk over a lifetime of use. Arsenic is a naturally occurring element and was found in the water at levels typical of the Posey County area.

- Water quality findings:

  - Water from many wells tested contained high concentrations of contaminants including high pH, total dissolved solids (TDS), salts, iron, and manganese. These contaminants can result in a bad taste or smell and can stain plumbing fixtures. Salts, iron, arsenic, and manganese may also result in health effects (see previous section).

  - Ten of the wells with an oily sheen and/or bubbling water were tested for petroleum-related contaminants. Total petroleum hydrocarbons (TPH) were elevated in 8 of the 10 water samples and the presence of oil and grease was detected in all 10 samples. Based on the methods used and the results reported, there is evidence that dissolved and degraded miscible petroleum is in water in the investigation area. The presence of petroleum-related contaminants along with methane in the well water in the area indicates that the drinking water is likely not suitable for drinking.

Recommendations

ATSDR makes the following recommendations:

1. Residents located in the EI investigation area that are experiencing poor water quality (e.g., smells or tastes bad, bubbly, noticeable oil sheen), reduce their exposure to the contaminants in well water by using another source of water for drinking and cooking (e.g., bottled water) or by treating their water. Residents that are concerned about the quality of their water may contact IDEM for further information on testing and treatment options. Residents should work with a water treatment specialist to ensure that a treatment system addresses all contaminants detected in their well water.

2. Until another source of water can be obtained:

   - Residents on salt-or iron-restricted diets, or who are taking lithium for medical reasons or sensitive individuals (e.g., children, pregnant women) should consult their physicians about the elevated amounts of these contaminants in their well water.

   - Residents with formula-fed infants should make infant formula with bottled water instead of tap water given the elevated concentration of manganese in their well water.

3. Based on the amount of methane detected in area groundwater:

   - Residents monitor their water for the presence of methane gas by checking their water for bubbles, or a cloudy or milky appearance.

   - Residents vent their wellheads and their homes to lower the risk of fire or explosion associated with the buildup of methane gas in the home.

   - Residents install a combustible gas detector in their home to monitor the level of gas in the air in their homes, using manufacturer's recommendations for placement and use. Residents should notify the Posey County Fire Department if a combustible gas detector in a home indicates a high concentration of gas in the air.

Public Health Action Plan

1. ATSDR will hold a Public Availability Session to provide information to the community regarding water quality issues found in the homes that were sampled.

2. Based on the EI results, the IDNR identified three abandoned oil production wells in the area that had been improperly plugged in the 1970s. These wells were properly replugged by IDNR in 2013. IDNR continues to investigate wells in the area and will replug additional wells as appropriate.

3. IDEM will provide information to the community regarding private well testing (http://www.in.gov/isdh/22452.htm) and well water treatment options upon homeowner's request.

4. Stakeholders have submitted the area to the Revolving Fund program for approval of a new municipal source of drinking water. The area has been approved, but funding has not yet been secured.

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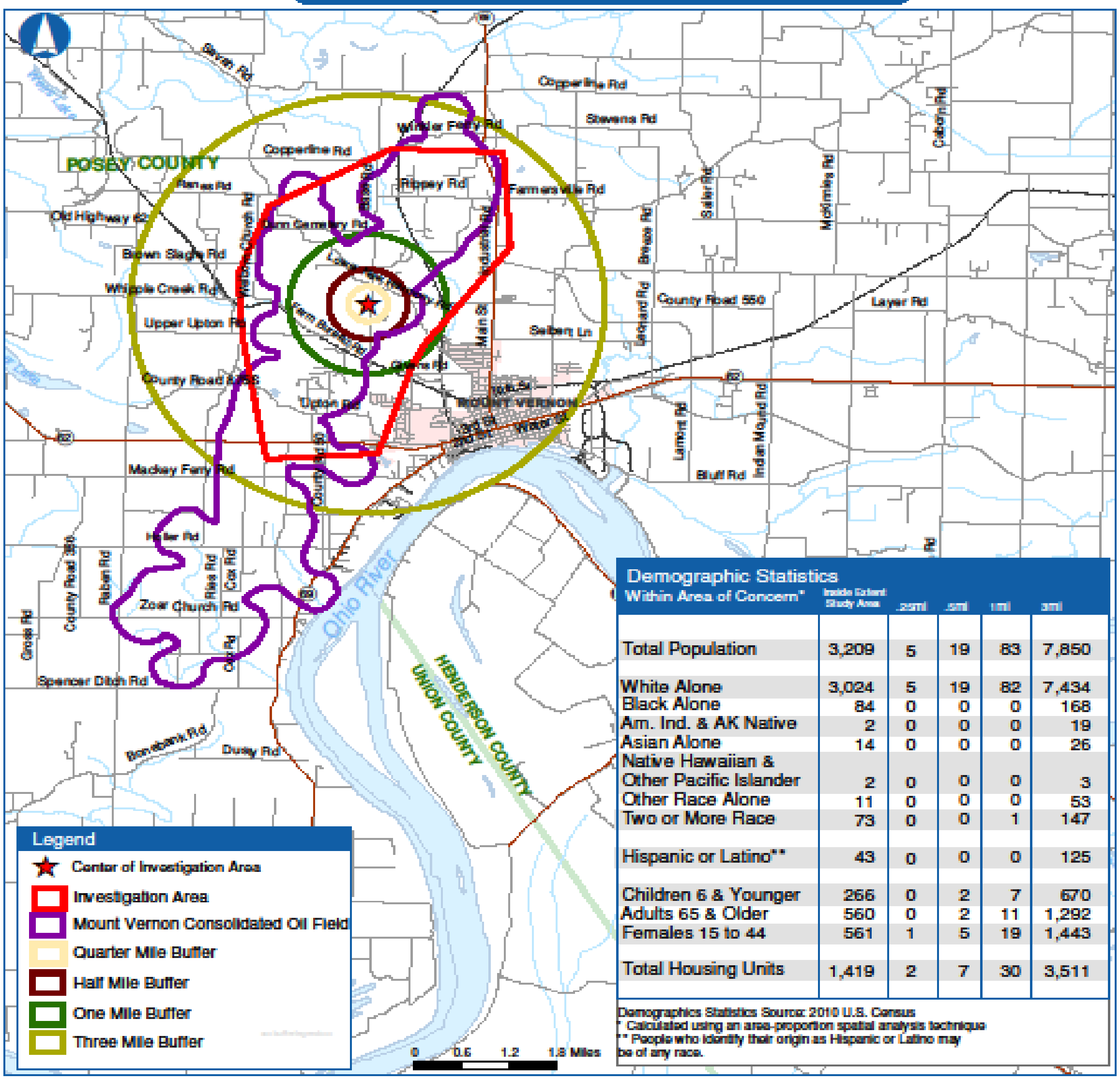
Appendix A: Exposure Investigation Maps

Figure 1: Posey County Exposure Investigation, Mount Vernon, IN – Investigation Area

Figure 2: Posey County Exposure Investigatiion, Mt. Vernon, IN: Demographic Statistics

FIGURE 2
Demographic Statistics
Posey County Exposure Investigation
MOUNT VERNON, IN



Demographic Statistics Within Area of Concern*	Inside Extent Study Area	.25mi	.5mi	1mi	3mi
Total Population	3,209	5	19	83	7,850
White Alone	3,024	5	19	82	7,434
Black Alone	84	0	0	0	168
Am. Ind. & AK Native	2	0	0	0	19
Asian Alone	14	0	0	0	26
Native Hawaiian & Other Pacific Islander	2	0	0	0	3
Other Race Alone	11	0	0	0	53
Two or More Race	73	0	0	1	147
Hispanic or Latino**	43	0	0	0	125
Children 6 & Younger	266	0	2	7	670
Adults 65 & Older	560	0	2	11	1,292
Females 15 to 44	561	1	5	19	1,443
Total Housing Units	1,419	2	7	30	3,511

Demographics Statistics Source: 2010 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.

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 Indiana West FIPS 1301 Feet

Centers for Disease Control and Prevention
Agency for Toxic Substances and Disease Registry
Geospatial Research, Analysis & Services Program

Appendix B: EI Protocol

Exposure Investigation Protocol for

Posey County, Indiana Private Well Water Evaluation

May 30, 2012

Cost Recovery: A0ZH

Prepared by

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I. PROJECT OVERVIEW

Summary

The purpose of this Exposure Investigation (EI) is to test private well water in homes located near Mount Vernon, in Posey County, IN. The Indiana Department of Environmental Management (IDEM) requested ATSDR assistance in this effort. Wells will be tested to determine the presence of chemical contaminants in the water that could impact the health of residents and may be associated with the presence of crude oil and natural gas in the region. The well water testing will be conducted using validated, state-of-the-science analytical methodologies. Results of this investigation will be used to inform the residents if their well water has contaminants above established health-based comparison values or at values that pose a health threat. Field work will be completed by September 30, 2012.

Extensive oil and natural gas production has occurred in Posey County, IN, since the 1930's. According to IDEM, residents in Posey County, Indiana have reported concerns about water quality in private drinking water wells since the 1960's. In 2008, IDEM became aware of residents' complaints of petroleum and oil field brine contamination in private drinking water wells. In January 2010, IDEM collected water samples from ten private/residential drinking water wells in Posey County, near the City of Mount Vernon and performed a limited analysis. Sampling identified eight of the ten wells contaminated with Total Petroleum Hydrocarbons (TPH). Chloride concentrations that exceeded the Secondary Maximum Contaminant Level (SMCL) were reported.

In this EI, water from 30 wells will be evaluated in the field with measurements of water quality characteristics (pH, temperature, specific conductance, dissolved oxygen and turbidity), organic vapor, combustible gases and floating oil thickness. Samples will be collected for laboratory analysis of major ions (i.e., chloride, sodium, iron, sulfate, etc.), trace elements, aromatic volatile organic compounds (VOCs), and gross alpha/beta radioactivity. In addition, up to 10 of the 30 samples with organic vapor, combustible gases or visible petroleum sheen will undergo further analysis for polycyclic aromatic hydrocarbons (PAHs), oil and grease, and total petroleum hydrocarbons (TPH). TPH includes heavy oils and natural gases (methane, ethane, ethane and propane).

ATSDR will select participants for the EI from a candidate list identified by the U. S. Geological Survey (USGS). Participants must reside near active oil and natural gas production areas and use their private well as the primary water source. The candidate wells for the EI selection will be based on USGS hydrogeological criteria. The ten residents who participated in the 2010 IDEM

evaluation will be given the opportunity to participate in this EI. Other residents will be invited to participate until a total of 30 participants are reached. As such, the test results from this investigation will be specific to these participants and are not generalizable to the community-at-large or to other populations.

ATSDR will prepare an Exposure Investigation report that summarizes the data, our conclusions about potential health hazards, and any recommendations for further actions by Indiana state or local agencies and property owners. Field laboratory test results and an ATSDR health interpretation will be provided to participants in the EI. A panel of water contaminants potentially associated with crude oil and natural gas production has been developed by ATSDR in conjunction with IDEM and USGS. The results will be evaluated by 1) screening water data against health-based comparison values, 2) estimating exposure doses, and 3) evaluating exposure estimates with appropriate toxicological data and determine if the water is safe to use as a potable water source.

Investigators and Collaborators

The IDEM requested this investigation (email communication 5/11/2011, ATSDR's M.Johnson to S. Metcalf). The ATSDR Exposure Investigation Team, Science Support Branch (SSB), Division of Community Health Investigations (DCHI) will be the lead for this Exposure Investigation. This EI will be a collaborative effort of the ATSDR DCHI (proposed) EI team and Central Branch along with IDEM, USGS and EPA Region 5. In addition, the Indiana Department of Natural Resources (IDNR) will be contacted to obtain additional information about petroleum production activity in the region, and the Posey County Health Department will be contacted to learn more about potential health complaints that may be associated with private well water consumption.

The ATSDR team will be accompanied by the IDEM during field activities. The specific roles of the EI team partners are as follows:

1. The ATSDR Team will:

    - Develop the EI protocol, Fact Sheet, Questionnaire, and Consent Form,
    - Work with USGS and IDEM to identify and recruit participants for the EI,
    - Obtain written consent of participants to collect private well water and administer a questionnaire,
    - Work with USGS and IDEM to collect water samples for field testing and laboratory

analysis,

- Make a health determination based on the results of water testing,
- Notify the participants of their individual test results,
- Keep the Posey County Health Department and the Indiana Department of Natural Resources (IDNR) informed about the progress and findings of the EI, and
- Write a report that summarizes the collective findings of the EI.

2. The Indiana Department of Environmental Management (IDEM) will:

- Assist ATSDR in the identification and recruitment of participants for the EI,
- Work with ATSDR to conduct private well water sampling,
- Work with USGS to provide interpretations of geochemistry and groundwater chemistry.

3. Through an Interagency Agreement (May 2012) with ATSDR, the Indiana office of the USGS will:[3]

- Review available data and provide hydrogeologic interpretation of the area and recommend private wells to test,
- Assist ATSDR and IDEM in the identification and recruitment of participants for the EI,
- Work with ATSDR and IDEM to develop a comprehensive field sampling plan and participate in reconnaissance of private drinking water wells and sampling of wells,
- Acquire and use necessary supplies and equipment for sampling, and transportation of samples for analysis,
- Provide assistance with data management, quality control and analysis of laboratory results of private well water samples,
- Coordinate analysis of the well water samples with the USGS National Water Quality Laboratory.
- Work with IDEM to provide interpretations of geochemistry and groundwater chemistry,

3 See page 33 for a specific list of tasks.

4. The EPA Region 5 will:

   - Provide technical support in the development of the EI protocol, and
   - Determine potential regulatory issues resulting from findings, if indicated.

5. The Indiana Department of Natural Resources (IDNR) will:

   - Assist ATSDR in the evaluation of gas and oil well characteristics located in Posey County to assist with identifying private water wells at highest risk of potential exposure.

6. The Posey County Health Department will:

   - Provide assistance with outreach to the community to recruit participants for the EI.

II. INTRODUCTION

Background (see below for references)

Activities that increase the production of existing and new oil and natural gas reserves have the potential to affect freshwater aquifers and wells that are the sole source of drinking water for many rural residences and communities. Surface spills and improper disposal of oil field brine and other wastes can degrade water from shallow aquifers. Increasingly, drilling and production operations of oil and natural gas employ hydraulic fracturing (“fracking”) techniques that involve the underground injection of solutions to create and support openings in the bedrock to improve the recovery of oil and gas. These solutions are typically a mixture of water, sand, and oil and gas formation liquids and can include small amounts of natural and man-made materials to improve the recovery of oil and gas. Since companies and operators are not required to disclose when these material are used or their chemical composition (with the exception of diesel fuel), it is difficult to determine if these materials have the potential for migrating into relatively deep freshwater aquifers and affecting drinking water wells. Since the state of Indiana does not have a monitoring program for private drinking water wells, little data exists to determine whether private wells located near drilling and production operations of oil and natural gas wells have contaminants at levels of health concern.

The extent of past or current hydraulic fracturing operations in Posey County, Indiana, is not known. ATSDR has been informed by the Indiana Department of Environmental Management (IDEM) in personal communications that in this region oil fields are periodically pressurized (water flooded) to facilitate and enhance petroleum production. This may be a mechanism for forcing petroleum into drinking water aquifers. In addition, some areas in Posey County undergo direct injection of natural gas into the subsurface within favorable geologic formation for the purpose of storing it for future use. Many unused or abandoned production wells, disposal wells, tests wells and bore holes exist in the region and it is unknown whether these wells are properly capped and plugged to prevent the stray migration of petroleum and oil field related materials into the environment.

The IDEM noted in personal communications to ATSDR that Posey County residents have reported private drinking water well water quality concerns dating back to the 1960's. In 2008 IDEM again became aware of residents' complaints of possible petroleum and oil field brine contamination in private drinking water wells. In January 2010, IDEM collected water samples from ten private/residential drinking water wells in Posey County, near the City of Mount Vernon. Sampling identified eight wells contaminated with Total Petroleum Hydrocarbons (TPH). The highest detection of TPH was 2,300 micrograms per liter (µg/L), which exceeds the 260 ug/L state residential water criteria. Chloride concentrations that exceed the 250 mg/L Secondary Maximum Contaminant Level (SMCL) were also reported. In addition, petroleum sheen was observed on one residential well; crude oil was observed inside the well casing of another.

IDEM presented these analytical findings to the ATSDR Region 5 Senior Representative to discuss whether area contamination posed a health threat to residents and requested ATSDR assistance in designing an Exposure Investigation to evaluate potential contamination and possible health implications. This information was then provided to the Exposure Investigation Team by personal communication from IDEM for consideration of performing an Exposure Investigation (EI).

Justification for the Exposure Investigation (EI)

Answers to four questions determine if an EI activity is warranted. These questions are used by the EI team to determine if an EI would be useful in better understanding whether public health impacts may be occurring as a result of environmental contamination.

1. **Can an exposed population be identified?**

Yes- It has been reported by IDEM that residents in the Mount Vernon area in southwestern Indiana have been complaining of crude oil and oil field brine contamination in their private wells for years. A January 2010 investigation by IDEM sampled 10 private wells in this area. Sampling results showed total petroleum hydrocarbons. The number of impacted private wells in the area is likely to be much larger.

2. Does a data gap exist that affects your ability to determine if a public health hazard

exists?

Yes- Although most of the well water samples exceed the cleanup goal for TPH of 260 µg/L, the lack of characterization of specific chemicals prevents a health-based evaluation. The January 2010 data had quality control issues and could not be used to make a health impact determination. Since 2010 more sensitive analytical methods have been developed and lower reporting limits and more sensitive analytical techniques for constituents from crude oil and natural gas production are now available.

3. Can an EI address the data gap?

Yes- A detailed analysis of the potential chemical constituents in the well water will allow a health-based evaluation for residents in the community. Analysis will identify mixtures of water quality characteristics, major ions, and trace metals. Using laboratory instruments for tentatively identified compounds could find non-target constituents, including chemical additives from hydraulic fracturing. Screening water samples in the field for organic vapor and combustible gas in water adds another set of data for distinguishing wells affected by aquifer contamination. Naturally occurring radioactive materials associated with oil field brine intrusion into freshwater aquifers can be indicated by analysis of gross alpha and beta radioactivity.

4. How would the EI results impact public health decisions?

More information on the chemical composition of area well water will provide important information regarding public health recommendations. The design of the EI has the intent of identifying wells with varying degrees of impact – from low levels that serve as an early warning to high levels that require action to stop exposure. Although municipal water is not available to residents in this area, point of use and whole house water treatment and other alternative water supplies can be considered. This information may also be useful in triggering potential regulatory action to address these concerns.

Objectives

The primary objectives of the EI include:

- Provide technical assistance to the state of Indiana to assess drinking water quality in areas of active oil and natural gas production and enhance recovery
- Assemble health-based comparison values to interpret EI data
- Provide recommendations to IDEM, local officials, and homeowners of actions that could be taken to reduce their risk of exposure to contaminants in the drinking water

III. METHODS

Exposure Investigation Design

The investigation area will focus on Posey County, Indiana, a rural area with a high density of oil and gas wells. The project will retest the 10 wells previously evaluated by IDEM, and then expand the testing to 20 additional residential water wells. If the owner of one or more of the previously tested wells chooses not to have their well retested, additional participants will be identified to reach a total of 30 wells[4]. We will focus on the area northwest of Mount Vernon, Indiana where the private water well testing by IDEM was previously performed. ATSDR, IDEM and the USGS have developed a sampling and analysis plan which identifies appropriate field screening and analytical methods for the drinking water analysis (Appendix A).

The EI will be completed in the following stages:

1. **Identification of Wells to be Included in the Sampling Program:**

The USGS and IDEM will assist ATSDR in identifying wells to be sampled. The USGS will compile and interpret public records and scientific information regarding bedrock geology and groundwater for a study area in the vicinity of Mt. Vernon area of Posey County, Indiana. These records and information will be state electronic data, paper files, and literature that include: lithologic logs from oil and gas exploration, oil and gas production, underground injection, and drinking water well construction; bore hole geophysical logs; aquifer tests; groundwater analysis; and references about bedrock geology and geomorphology. Technical personnel in the IDEM and IDNR will be consulted for sources of information. The USGS will interpret the depth, thickness, areal extent, flow conditions, and uses of freshwater aquifers in the study area and identify potential relations to bore holes, wells, and activities that could allow petroleum and oil field brine to contaminate freshwater aquifers in the study area. Based on available records, USGS and ATSDR will identify approximately 40 domestic wells as candidates for testing from which the final 30 wells will be determined. To participate in the EI the resident must be the property owner.

Given that numerous petroleum wells (both oil and gas) are located in Posey County, potential impacts of drilling and production activities on groundwater quality will be assessed. In addition to the hydrogeological criteria from public records and scientific information described above, the wells will be identified by evaluating the depth of the private water well, the location of the water well in relation to oil and gas production activities, and whether community complaints are

4 30 wells were chosen for this EI based on the funds available to provide the level of laboratory analysis required from the USGS laboratory as developed by ATSDR in partnership with USGS.

associated with any wells in the area.

Once the 40 wells are identified, owners and property addresses of the well be obtained using information from the water well database and a letter and fact sheet (Appendix B) will be sent that outlines our objectives and request them to consider participating. The letter and fact sheet will specify that only residences occupied by the owner will be eligible for inclusion in the EI. An example of the letter and fact sheet is provided in Appendix B.

2. **Exploratory Visit to Identify Sampling Locations**

The site team will consist of personnel from ATSDR, USGS, and IDEM. In addition, a meeting will be arranged with the Posey County DOH and IDNR.

- The wells identified for sampling will be evaluated in the field to determine feasibility based on both accessibility and owner cooperation. To accomplish this, we will make an in person visit and:
    - Follow up on the introductory letter to discuss the sampling effort.
    - Evaluate whether the well can be successfully sampled if they agree to participate..
    - Leave another fact sheet at the residence if no one is home. The fact sheet which explains our request for sampling and includes contact information where we can be reached.
    - If additional participants are needed we will attempt to contact the identified potential participants up to a maximum of three times to determine if they would be interested in participating.
- Volunteers will not be able to participate if:
    - They do not provide written consent, which includes permission to share deidentified well water results with Indiana state agencies and other federal agencies;
    - Their water cannot be successfully sampled between the well and any existing treatment system; or
    - They are not the property owner.

- The team will conduct a field exercise during the site visit to ensure required equipment and supplies have been obtained and team members are consistently following procedures.

3. **Questionnaire**

In addition to water sampling, a brief questionnaire about water quality in the home and basic demographic information that will take an estimated 20 minutes will be administered (See Appendix C).

Questionnaire responses will be entered directly into a password protected computer using Rapid Data Collector version 2.1 data base. Only ATSDR personnel will enter data and have access to the computer. Information collected from the questionnaire will be used for interpreting analytical results. The water use habits of each participant and the amount and quality of filtering systems, if any, may impact the potential for exposure to identified contaminants Information on characteristics found on a participant's property (e.g., septic tanks, oil wells, etc.) might provide information to help explain the results. Demographic information will be used to qualitatively describe the EI participants. In addition, the question about length of residence at the current address will define the potential duration of exposure, if any, for each resident.

ATSDR will provide each participant a letter with their test results and our interpretation (Appendix F).

4. **Private Well Sampling:**

- Equipment calibration, sample collection, field screening, and chain of custody will be conducted according to a field sampling plan developed by USGS. A full description of the sampling effort is provided in Appendix A.

- The sampling team will consist of personnel from ATSDR, USGS, and IDEM. A minimum of two sampling teams will be identified for the effort. Each team will use the following field equipment, which will all be provided by USGS: photoionization detector/flame ionization detector (PID/FID), interface meter, multiparameter meter, turbidimeter, and a GPS.

- As appropriate, the sampling teams will coordinate with local IDNR inspectors and the Posey County Health Department.

- Water sampling will be completed at a raw water tap, where available. The sample will be taken from a source prior to any treatment system if one is in place. If a sample cannot be obtained prior to a treatment system, the well will not be tested.. The intent of the EI is to test water that has not been treated to allow an analysis of fresh groundwater coming from the aquifer.

Data Collection/Sampling/Analysis Procedures

The following water quality parameters will be evaluated in the field (Table 1A):

- A photoionization detector (PID) will screen for organic vapor in the headspace of a well water sample container.
- A flame ionization detector (FID) will screen for combustible gases, including methane, in the headspace of a well water sample container.
- A multi-parameter meter will measure basic groundwater properties, such as pH, specific conductance, temperature, and dissolved oxygen. A separate meter will screen turbidity.
- An interface meter will determine the thickness of floating oil in a water sample if petroleum sheen is present (sensitivity of approximately 3 mm). This instrument will be used in a well casing to measure the thickness of floating oil and depth to water.

Samples for gross alpha and gross beta radioactivity will be pack and shipped each evening after they are collected. All other samples will be packed and stored appropriately by USGS and shipped to the USGS National Water Quality Laboratory at the conclusion of the investigation. Quantitative analysis will be done for the following parameters (Table 1B):

- Major ions, including chloride
- Trace Elements
- Volatile organic compounds (VOCs) including benzene, toluene, ethylbenzene and xylenes (BTEX),
- Tentatively identified compounds (TICs)
- Gross alpha and gross beta radioactivity

For those wells with petroleum sheen and/or PID/FID readings indicative of volatile contamination in the water, the following additional parameters will be evaluated for a maximum of 10 wells. If greater than 10 wells are identified with petroleum sheen, only the 10 samples that appear to have the greatest level of contamination based on appearance at the time of sampling and PID/FID readings will be selected for evaluation of the optional parameters (Table 1C)[5].

- Polycyclic Aromatic Hydrocarbons (PAHs)
- Semi volatile organic compound (SVOC) and associated method TICS
- Total Petroleum Hydrocarbons (TPH)

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5 10 additional samples was chosen based on funds available to provide the level of laboratory analysis needed by the USGS laboratory as developed by ATSDR in partnership with USGS.

- Oil and Grease (hexane extractable materials, HEM, and silica-gel treated HEM)
- Hydrocarbons, including methane, ethane, ethane, propane)

Quality assurance and Quality Control (QA/QC)

Analysis of water and quality control samples will be provided by the USGS NWQL. The turnaround time from sample receipt to laboratory reporting will be approximately 30 days or less. Laboratory data will be transmitted electronically through the USGS NWIS. Digital data reports will be provided through a continuous dialogue and partnership of USGS Indiana scientists with the ATSDR Exposure Investigation Team.

The 30 water samples will be analyzed for a list of parameter groups using methods listed in Tables 1B and 1C. The individual constituents and their reporting limits for each parameter group are listed in Appendix E. Field determinations include measurements of 4 water quality characteristics, turbidity, and alkalinity; quantification of total organic vapor, natural gases including methane; measurement of floating oil thickness; plus observations of color, oil, and odor. The laboratory will treat each sample and each set of constituents in a parameter group individually. The laboratory will use the field determinations data submitted with the analytical services request for each sample to identify the samples with levels of organic vapor, specific conductance, or visible oil that have the potential to degrade analytical equipment integrity and affect successive samples in the same analytical run. Laboratory analysts will separate and analyze these potentially contaminated samples from those with field determinations data showing no organic vapor, relatively low specific conductance, and no visible oil. The potentially contaminated samples may require a series of dilutions, based on the highest constituent concentration. The objective is to detect constituents present at the lowest reporting limits. If a sample is diluted for a specific set of constituents in that parameter group, the reporting limits will be raised proportionally for the other constituents from that group analyzed in that sample. The laboratory analytical methods in this proposal have reporting limits for constituents in Appendix E that are as much 100 times lower than those used for IDEM's analysis of January 2010 samples from private wells near Mt. Vernon, resulting in a more robust data analysis.

Appropriate QA/QC samples will be analyzed to supplement the routine laboratory quality assurance required for each analytical method, plus other measures conducted as part of the USGS NWQL quality assurance plan. The QA/QC samples provide measurements of sample representativeness, reproducibility, and matrix interferences associated with analytical results. The QA/QC samples for the 30 water samples consist of 3 trip blanks, 3 sequential duplicates, 3 laboratory matrix-spike samples, and one blank source solution. Parameters analyzed in the different samples vary and are listed in table 5 of Appendix A.

Appendix A provides the USGS well water sampling plan including screening and laboratory analyses. The following tables provide the reasoning for including analytes, analysis methods, and environmental screening values.

Table 1: Sampling Parameters for Posey County Private Well Water Quality EI

Parameter	Justification	USGS Method	Screening Value[a]

Table 1A: Field Analyses for all 30 Water Samples

Water quality characteristics: pH, temperature, Specific Conductance, Dissolved Oxygen, turbidity, Total Dissolved Solids (TDS)	These characteristics will allow for evaluation of the aquifer.	field analysis with multi-parameter meter	pH: 6.5-8.5 (SMCL) TDS: 500 mg/L (SMCL) Turbidity: TT
VOCs and combustible gases, including methane	VOCs and Methane are associated with petroleum activities	field analysis with FID / PID	Results will be used to identify samples to be sent for Optional Parameter analysis (Table 1C)

Table 1B: Parameters to be Evaluated for all 30 Water Samples

Major Ions: bromide, calcium, chloride, fluoride, iron, magnesium, manganese, potassium, silica, sodium, sulfate	These ions characterize the aesthetic, cosmetic and technical effects on water being used by the community.	LS2701, LC3166	See Appendix E (Table E.1) for list
Trace Elements : Aluminum, Antimony, Arsenic, Barium,	Test for increased minerals in drinking	LS2710	See Appendix E (Table E.2) for list

Beryllium, Boron, Cadmium, Chromium, Cobalt, Copper, Lead, Lithium, Magnesium, Molybdenum, Nickel, Selenium, Silver, Strontium, Thallium, Uranium, Vanadium, Zinc	water.		
VOCs and associated method Tentatively Identified Compounds (TICs)	Some VOCs (e.g, BTEX) are associated with petroleum activities	LS2020 custom	See Appendix E (Table E.3) for list
Gross alpha and gross beta radioactivity (72-hour and 30-day counts)	Gross alpha and gross beta radioactivity are associated with naturally occurring radioactive elements in aquifers.	LC2806 (RL = 3.0 pCi/L for gross alpha and 4.0 pCi/L for gross beta)	alpha (15 pCi/L) beta (4 mrem/yr)

Table 1C: Optional Parameter Groups (on max of 10 samples with visible petroleum sheen)

Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are associated with petroleum.	EPA 8310	See Appendix E (Table E.4) for list
SVOC and associated method TICs	SVOCs are associated with petroleum.	EPA 8270C	Chemical-specific evaluation
Total Petroleum Hydrocarbons (TPH)	TPH are associated with petroleum and have been detected in resident's well water.	EPA 8015D (RL = 0.25 mg/L; diesel range organics = 0.25 mg/L; oil range organics = 0.5 mg/L)	100 ug/L (diesel range); 220 ug/L (gasoline range)[b]
Oil & Grease (HEM) (n-Hexane Extractable Material) & Total Recoverable Hydrocarbons	HEM is associated with petroleum.	EPA 1664A (RL = 5.0 mg/L)	NA
Hydrocarbons including methane, ethane, ethane, and propane	Evaluation of these hydrocarbons will allow for an assessment of potential explosivity of the water. In addition, it will allow for an evaluation of the petroleum source (thermogenic vs biogenic).	RSK-175 (RL = 0.5 ug/L)	NA

USGS = US Geological Survey
VOCs = Volatile Organic Compounds
BTEX = Benzene, Toluene, Ethylbenzene, Xylene
SVOC = Semivolatile Organic Compounds
PAH = Polycyclic Aromatic Hydrocarbons
TPH = Total Petroleum Hydrocarbons
FID = Flame Ionization Detector
PID = Photoionization Detector
NA = Not Available
NR = Not Reported
RL = Reporting Limit
pCi/L = picocurie per liter
mg/L = milligram per liter

mrem/yr = millirem per year
ug/L = microgram per liter
SMCL = EPA Secondary MCL
SVOC = Semi Volatile Organic Compound
TIC = Tentatively identified compounds
TT = Treatment Technique
VOC = Volatile Organic Compound
a - Screening Values were either MCL or CV values.
b - Screening values from IDEM RISC guidance (June, 2010)

The results of the sampling will be compared to appropriate Comparison Levels (CVs), Maximum Contaminant Levels (MCLs), or EPA's Regional Screening Levels (RSLs), as available (Appendix E). For those contaminants that exceed the screening value, ATSDR will assess the potential health impact of the contaminants present and make recommendations on how participants may reduce potential exposure from their raw water. Participants who use a filtering system may wish to consider further testing to determine whether contaminants are being reduced or eliminated from the drinking water. Pursuing additional testing is not part of this EI.

Records management

Technical support from USGS scientists will include data management for results of laboratory analysis and field determinations, along with sample site, water sample, and quality-control information. The USGS National Water Information System (NWIS) is the web-accessible national data base (http://waterdata.usgs.gov/nwis) used to archive all water information of the USGS. Generally, NWIS is an open public data base, but new data can be coded to temporarily delay upload to the public side of the data base if needed. The water-quality data component of NWIS, called QWDATA, will be used to archive a geographically referenced site identification file for each private well that is sampled. A unique record will be established for each water sample and the field determinations and analytical data will be archived for each record. Quality Control (QC) data are archived in a unique record in QWDATA. Laboratory results are digitally loaded into the QWDATA as they are completed. If needed, groundwater and well information can be archived in the Groundwater Site Information component of NWIS, linked to the site identifier. Data retrieval from NWIS is available in pre-formatted tables with numerous options and in delimited flat files that can be loaded into spreadsheets and other data bases. USGS scientists will provide data entry, retrieval, compilation, and verification.

Because information provided to Indiana state agencies must be made public if requested we will only share information about participants' well water results with other state and federal environmental and public health agencies if the participant provides consent. ATSDR will keep all personal information pertaining to the identification of owner's names and addresses confidential and destroyed it after completion of the final report. Electronic data will be kept by ATSDR in a password protected computer. Paper copies will be stored in a locked file cabinet. All laboratory samples will be coded so personal information is not available to the laboratory or in the report. If there is a need for ATSDR to share information with other agencies, we will not provide personal contact information (name, address, telephone number, email) without prior consent.

IV. RISK/BENEFIT INFORMATION

There is no perceived risk that will occur to participants as a result of water sampling. Participants will need to be at their residence when water samples are taken and team members may need to enter the participants' home to evaluate water treatment systems if present. This may inconvenience the home owner. In addition the home owner will need to complete the survey questionnaire which will be administered by a member of the EI team. The survey questionnaire will be completed electronically (laptop) and will take 20 minutes to complete. Completing both the questionnaire and water sampling will take about one hour.

The potential benefit to the participants of this EI is that they will learn if they do or do not have contaminant levels above comparison values in their drinking water. If elevated levels are found, appropriate recommendations will be made to reduce participants' exposures.

V. INFORMED CONSENT PROCEDURES

This is a voluntary activity. Potential participants will have an opportunity to discuss the risks and benefits of participation in this investigation with a member of the EI team either in person or via telephone. In addition a fact sheet describing the exposure investigation will be provided to potential participants (Appendix B). A resident who meets the criteria for participation and wants to participate must provide written Informed Consent (Appendix B) for water testing and questionnaire administration. They will have the opportunity to discuss the investigation throughout the EI. They can decide not to participate at any time without penalty.

VI. PROCEDURES FOR NOTIFYING PARTICIPANTS OF INDIVIDUAL AND OVERALL RESULTS

ATSDR will send a letter (Appendix F) to each participant with their test results along with our health interpretation, and our contact information to discuss their results. If contaminants are found, the letter will also include recommendations for how exposures may be reduced.

ATSDR will also prepare a written report presenting the overall EI findings. This report will contain only aggregate data and will not contain individual identifiers. The report will be available to the public and federal, state, and local environmental and public health agencies. Following completion of the final report a public availability session will be held in Mount Vernon, Indiana to give participants and other interested parties an opportunity to discuss the report and ask related questions.

VII. ASSURANCES OF PRIVACY

Privacy will be protected to the fullest extent possible by law. Because information provided to Indiana state agencies must be made public if requested, ATSDR will only share information about well water results with other state and federal environmental and public health agencies if given permission by the participant, ATSDR will not share personal contact information without the participant's consent. ATSDR will keep all personal information pertaining to the identification of owner's names and addresses private and it will be destroyed after completion of the final report. Electronic data will be kept by ATSDR in a password protected computer. Paper copies will be stored in a locked file cabinet. All laboratory samples will be coded so personal information is not available to the laboratory or in the report.

Reports produced during this investigation will give only group information and will not identify specific individuals by name or address. ATSDR will prepare a report summarizing the findings of the investigation that will not reveal personal identifiers.

The consent form will require permission from the participants for ATSDR to share their test results with other federal and state health and environmental agencies in order to participate in the EI. Individual test results that include personal contact or identifying information may be released only to other federal, state, and local public health and environmental agencies with the consent of the participant. These agencies must also protect this private information to the extent the law allows.

VIII. ESTIMATED TIME FRAME

- The sampling and laboratory analysis will be completed prior to September 30, 2012.
- Letters to EI participants providing water sample test results and recommendations, as indicated, are estimated to be sent 12-16 weeks after water sampling is completed.
- The Final Report is estimated to be completed by September 30, 2013.

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APPENDICES

Appendix A:
- USGS – Funded Proposal for Technical Assistance and Laboratory Analysis

Appendix B:
- Posey County EI Invitation Letter Fact Sheet for Participation Solicitation

Appendix C
- Consent Form

Appendix D
- Questionnaire

Appendix E:
- List of CV/MCL/RL values for the Sampled Parameters

Appendix F:
- Individual Results Cover Letter

Appendix A: US Geological Survey Proposal for the ATSDR Exposure Investigation Team

Technical Support for Hydrogeology, Geochemistry, and Groundwater Quality and Analysis of Water Samples from Private Wells near Mt. Vernon, Posey County, Indiana
April 27, 2012

Martin Risch, Research Hydrologist, Indiana Water Science Center, US Geological Survey

Overview

The Exposure Investigation Team of the Agency for Toxic Substances and Disease Registry (ATSDR) of the Federal Centers for Disease Control requested technical support from the US Geological Survey (USGS) for the proposed ATSDR evaluation of water from private wells in Posey County, Indiana in 2012. This USGS proposal describes the approach, tasks, outputs, and budget costs for USGS technical support through an Interagency Agreement with ATSDR. This USGS proposal is based on communications between scientists at the USGS Indiana Water Science and medical/public health personnel of the ATSDR in Atlanta and Chicago during December 2011 through April 2012. This proposal includes minor revisions from the February 2, 2012 and April 4, 2012 versions made in response to additional information and decisions since that version was prepared. This proposal includes recommendations based on review and approval by the USGS National Water Science Field Team in March 2012 and USGS Publications Approving Official in April 2012.

The ATSDR was contacted by the Indiana Department of Environmental Management (IDEM) Office of Emergency Response because analysis of water samples from an IDEM complaint investigation in January 2011 indicated the presence of petroleum and oilfield brine constituents in private wells near Mt. Vernon in Posey County. According to a summary by ATSDR prepared with information from Indiana Department of Natural Resources and Indiana Geological Survey data bases, the affected private wells are in an area of Indiana that has approximately 7,000 wells related to oil and gas production, exploration, storage, and disposal, along with approximately 1,700 private water-supply wells. The purposes of the evaluation in Indiana proposed by ATSDR are to: 1) obtain information about water quality from private wells in Posey County; 2) provide recommendations for reducing risks from exposure (if any) to contaminants in drinking water; and 3) extend the methods and results of their evaluation to similar situations in Indiana and other states.

This USGS proposal has three parts. The first part describes technical support for hydrogeology, geochemistry, and groundwater quality provided by USGS scientists. USGS will interpret available hydrogeological information to identify candidates for private well sampling. USGS will assist ATSDR with reconnaissance and sampling water from 30 private wells, following a field sampling plan developed by USGS as part of this proposed technical assistance. USGS will provide all the needed equipment and supplies and a mobile laboratory. USGS will compile data from laboratory analysis and field measurements for ATSDR and provide calculations of geochemistry and groundwater quality. The USGS will present methods, data results, and calculations in an online USGS information product.

The second part of this proposal describes the parameters, methods, reporting limits, related services, and costs for the USGS National Water Quality Laboratory (NWQL) to analyze water samples from 30 private wells plus supplemental quality-control (QC) samples. USGS will make field determinations of water-quality characteristics, total organic vapor, and natural gases in the water samples. Required supplies and equipment are included. Sample information and laboratory data will be archived in the USGS National Water Information System. Digital data reports will be provided through a continuous dialogue and partnership of USGS Indiana scientists with the ATSDR Exposure Investigation Team.

The third part of this proposal lists the estimated costs for the part one and two.

Technical Support for Hydrogeology, Geochemistry, and Groundwater Quality

1.1 Hydrogeological interpretation

USGS will compile and interpret public records and scientific information regarding bedrock geology and groundwater for a study area in the vicinity of Mt. Vernon area of Posey County, Indiana. These records and information will be electronic data, paper files, and literature that include: lithologic logs from oil and gas exploration, oil and gas production, underground injection, and drinking water well construction; borehole geophysical logs; aquifer tests; groundwater analysis; and references about bedrock geology and geomorphology. Technical personnel in the IDEM and Indiana Department of Natural Resources will be consulted for sources of information. The USGS will interpret the depth, thickness, areal extent, flow conditions, and uses of freshwater aquifers in the study area and identify potential relations to boreholes, wells, and activities that could allow petroleum and oilfield brine to contaminate freshwater aquifers in the study area. Based on available records, USGS will identify approximately 40 private water supply wells as candidates for water sampling by the ATSDR and USGS.

1.2 Comprehensive field sampling plan

USGS will develop a comprehensive field sampling plan that describes the protocols, equipment, supplies, quality control, record keeping and data management. The plan will reference standard and customized USGS techniques to collect water samples from private water wells and to make field determinations of water-quality characteristics, organic vapor, and natural gases. Water samples will be collected from a faucet supplying untreated water from the private water well. USGS will not plan to open a private wellhead for sample collection, inspection, or measurement unless required by the ATSDR and if the homeowner gives written permission. The plan will list the equipment and supplies to fill sample containers and complete sample processing for parameter groups and constituents identified in the second part of the approach section of this proposal. The plan will include preparation of quality-control samples. The plan will include recordkeeping for sample site information, field data, analysis request, and chain of custody. The plan will include equipment calibration and field measurements. The plan will include steps for packing and shipping samples. The plan will refer to data management requirements. The draft field sampling plan will be discussed with the ATSDR prior to the field reconnaissance and a final field sampling plan will be rehearsed during the field reconnaissance.

1.3 Reconnaissance and sampling water from private wells

USGS will participate in a multi-day reconnaissance of the study area with ATSDR to inspect the candidate private wells for sampling, meet with local officials, and rehearse the field sampling plan. ATSDR will be responsible for obtaining permission from homeowners for USGS and ATSDR to collect water samples. USGS will support ATSDR by collecting water samples from 30 private wells, preparing quality-control samples, making field determinations, and packing/shipping samples according to the field sampling plan. This proposal includes per diem, and lodging for the USGS scientists based on a total of 8 days and 6 nights for the reconnaissance and sampling.

1.4 Supplies, equipment, and transportation

USGS will prepare sampling kits and provide related supplies. USGS will provide, calibrate, and maintain equipment to support two field teams. Equipment includes multi-parameter meter, turbidity meter, PID/FID organic vapor meter, oil-water interface meter, GPS unit, sample chamber, flow manifold, sample processing pump, and alkalinity titration kit. USGS will provide a mobile water quality laboratory for transporting supplies and equipment and for doing instrument calibration, sample processing, and some field determinations under controlled conditions. Shipping will be direct charged to the ATSDR unless otherwise specified in the Interagency Agreement.

1.5 Data management

Technical support from USGS scientists will include data management for results of laboratory analysis and field determinations, along with sample site, water sample, and quality-control information. USGS will provide data entry, retrieval, and compilation. The USGS National Water Information System (NWIS) is the national data base used to archive all water information of the USGS. NWIS is used to electronically transfer data from the USGS laboratories to project scientists. For the project described in this proposal, sample site information and water sample analysis will be coded for internal use. Personal information such as a homeowner name or address will not be included. Data retrieval from NWIS is available in pre-formatted tables with numerous options and in delimited files that can be loaded into spreadsheets and other data bases. USGS will complete data verification and validation before supplying a final set of data to ATSDR in an acceptable format.

1.6 Information product

The Fundamental Science Practices of the USGS (http://www.usgs.gov/fsp/) underlie USGS science activities, uphold the USGS scientific reputation, and underscore the mandate to provide reliable science to address pressing societal issues. The Fundamental Science Practices also promote the broad release and communication of results of USGS science activities in information products.

The project described in this proposal will result in hydrogeologic and water-quality information from the USGS that are linked with, but different from the health–based interpretations of the ATSDR. The data from the field determinations and laboratory analysis from this project require calculations by USGS, for example, to illustrate water types for major ions, chemical ratios, statistical summaries, and quality control values. The USGS methods and final data from this project will be presented in an Open File Report (OFR) for online distribution after the ATSDR report is released. The OFR will not indicate it was prepared in cooperation with ATSDR. Rather, it will be a citable reference available from the USGS directly. The OFR is a peer-reviewed information product in the USGS report series for timely release of data and supporting material. ATSDR will be asked to provide technical review and approval of the OFR before it is submitted for USGS approval. The USGS will be responsible for online posting of the approved OFR.

Laboratory Analysis and Related Services

2.1 Considerations for water analysis

Freshwater aquifers in the vicinity of oil and gas production can be contaminated when deep subsurface pressure is increased and fluids are added to enhance production. Brine, crude oil, and natural gases from saline aquifers and bedrock formations, potentially mixed with the introduced fluids, can move into the shallow freshwater aquifers through open/poorly plugged and abandoned boreholes or through flaws in the annular seal of production and disposal well casings. Natural and expanded fractures and faults in the bedrock provide other avenues for migration of fluids. If freshwater aquifers are contaminated, private water-supply wells drawing from these aquifers likely will exhibit a spectrum of parameters and constituents caused by mixing of freshwater with brine, crude oil, natural gases, and subsurface fluids. This spectrum of dissolved, partly dissolved, and non-aqueous phase contaminants could range from small concentrations of dissolved organic chemicals, trace elements, and salts to high concentrations of organic chemicals, trace elements, salts, and floating crude oil. Some of the trace elements can be a source of radioactivity. The strength of the mixtures could fluctuate and it will be important to identify wells with dilute mixtures and low levels of some contaminants because of potential health risks and to serve as an early warning of potential risk.

2.2 Parameter groups for water analysis

Parameter groups in table 1 were selected to include constituents of oilfield brine and petroleum. Four **basic parameter groups** will be analyzed in 30 water samples.

- <u>Major cations and anions</u> include constituents of brine and can be used to characterize mixtures of freshwater and oilfield brine. Secondary (aesthetic) drinking water standards are available for some of the constituents in this group. Bromide and chloride ratios can be used to identify brine.
- <u>Dissolved trace elements</u> occur naturally at different concentrations in freshwater and saline aquifers and can be used to characterize mixtures of freshwater and oilfield brine. Primary drinking water standards are available for some of the constituents in this group.
- <u>Aromatic volatile organic compounds</u> are soluble constituents of petroleum. Primary drinking water standards are available for some of the constituents in this group. Tentatively identified compounds (TICs) are included, as explained here. The analytical method is sensitive to non-target constituents and when the instrument response is compared with a digital library of compounds, some of these non-target constituents can become TICs with concentrations estimated.
- <u>Gross alpha and beta radioactivity</u> are emitted by naturally occurring radioactive elements found in groundwater from saline and freshwater aquifers. Some of the radionuclides emitted from these elements are short lived and some elements have decay products that differ in their emissions of gross alpha and beta radioactivity over time. This proposal includes analysis of water within 72 hours of collection and again after 30 days because it has the best likelihood of detecting radioactivity from short lived and decay product radionuclides. Primary drinking water standards are established for gross alpha and beta radioactivity.

Optional parameter groups will be added to the analysis for 10 of the 30 water samples. The 10 samples will be selected on the basis of field determinations of organic vapor and natural gases in the water and observed/measured petroleum.

- Polycyclic aromatic hydrocarbons (PAHs) include soluble constituents of petroleum. Primary drinking water standards are available for some of the constituents in this group. PAHs are part of the list of constituents in an organic compound analytical method group called semi-volatile organic compounds. TICs from this group will be included with the PAHs.
- Petroleum hydrocarbons, plus oil and grease are analyzed by separate but complementary methods that quantify the presence of petroleum hydrocarbons and oil in water. Petroleum hydrocarbon analysis includes the diesel range C10 – C28 hydrocarbons and the motor oil range C28– C36 hydrocarbons.
- Dissolved natural gases include methane, ethane, and ethene. These gases are important because they are associated with oil and gas production and can be a problem in water supplies.

2.3 Laboratory analysis

Analysis of water and quality control samples will be provided by the USGS NWQL. The turnaround time from sample receipt to laboratory reporting will be approximately 30 days or less. Laboratory data will be transmitted electronically through the USGS NWIS. Digital data reports will be provided through a continuous dialogue and partnership of USGS Indiana scientists with the ATSDR Exposure Investigation Team.

The 30 water samples will be analyzed for a list of parameter groups using methods listed in table 1. The individual constituents and their reporting limits for each parameter group are listed in appendix 1. Field determinations (table 2) include measurements of 4 water quality characteristics, turbidity, and alkalinity; quantification of total organic vapor, natural gases including methane; measurement of floating oil thickness; plus observations of color, oil, and odor. The laboratory will treat each sample and each set of constituents in a parameter group individually. The laboratory will use the field determinations data submitted with the analytical services request for each sample to identify the samples with levels of organic vapor, specific conductance, or visible oil that have the potential to degrade analytical equipment integrity and affect successive samples in the same analytical run. Laboratory analysts will separate and analyze these potentially contaminated samples from those with field determinations data showing no organic vapor, relatively low specific conductance, and no visible oil. The potentially contaminated samples may require a series of dilutions, based on the highest constituent concentration. The objective is to detect constituents present at the lowest reporting limits. If a sample is diluted for a specific set of constituents in that parameter group, the reporting limits will be raised proportionally for the other constituents from that group analyzed in that sample. The laboratory analytical methods in this proposal have reporting limits for constituents in appendix 1 that are as much 100 times lower than those used for IDEM's analysis of January 2010 samples from private wells near Mt. Vernon. For example, IDEM and USGS reporting limits are compared in tables 3 and 4.

2.4 Quality control (QC)

The QC samples to be analyzed will supplement the routine laboratory quality assurance required for each analytical method, plus other measures conducted as part of the USGS NWQL quality assurance plan. The QC samples provide measurements of sample representativeness, reproducibility, and matrix interferences associated with analytical results. The QC samples for the 30 water samples consist of 2 field blanks, 2 equipment blanks, 2 trip blanks, 3 sequential duplicates, and 3 laboratory matrix-spike samples. Parameters analyzed in the different QC samples vary and are listed in table 5.

Estimated Costs

The USGS Indiana Water Science Center has entered into an Inter-Agency Agreement with ATSDR (May 23, 2012) and accept funds to support the costs for technical support and laboratory analysis in this proposal.

Technical support for hydrogeology, geochemistry, and groundwater quality

Estimated costs are provided for two USGS scientists and related expenses for the activities in sections 1.0 through 1.6.

Budget category	Cost
Salary and benefits	$25,500
Transportation and travel	$ 1,950
Supplies and equipment	$ 2,400
Technical overhead service	$17,950
Subtotal	$47,800

Laboratory analysis and related services

Estimated costs are provided for laboratory analysis of basic parameter and optional parameter groups, plus quality-control samples and supplies in sections 2.3 and 2.4 and the supporting tables and appendix.

Budget category	Unit Cost	Cost
Basic parameters (30 samples)	$782.27	$23,468
Optional parameters (10 samples)	$501.16	$ 5,012
Quality-control (12 samples)		$ 6,484
Expendable supplies		$ 2,715
Technical overhead service		$ 4,521
Subtotal		$42,200

Estimated total cost

Budget category	Cost
Technical support	$47,800
Laboratory analysis	$42,200
TOTAL	**$90,000**

Table 1. Parameter groups and analytical methods for water samples

Basic parameter group[1]	Analytical method(s)[2]	Method description[3]
Major cations and anions	LS2701, LC3166	IC
Trace elements	LS2710	ICP/MS
Aromatic VOCs and TICs	LS4435	GC/MS
Gross alpha and beta radioactivity (72 hours and 30 days)	LC2806	Gross alpha (Th-230 curve) Gross beta (Cs-137 curve)
Optional parameter group[1]	**Analytical method(s)[2]**	**Method description[3]**
Polycyclic aromatic hydrocarbons	EPA8310	HPLC
SVOC TICs	EPA8270C	HPLC
Total petroleum hydrocarbons DRO diesel range organics (C10-C28) MRO motor oil range organics (C28-C36)	EPA8015D	GC/FID
Oil and grease and total recoverable petroleum hydrocarbons	EPA1664A	HEM and SGT
Dissolved natural gases	EPA 8015B	GC/FID

[1] VOCs, volatile organic compounds; TICs, tentatively identified compounds; SVOC, semivolatile organic compound
[2] LC, USGS lab code; LS, USGS lab schedule; EPA, Environmental Protection Agency SW846 method
[3] IC, ion chromatography; ICP/MS, inductively coupled plasma/mass spectrometry; GC/MS, gas chromatography/mass spectrometry; HPLC, high performance liquid chromatography; GC/FID, gas chromatography/flame ionization detector; HEM, hexane extractable material; SGT, silica gel treated hexane extractable material

Table 2. Field determinations and methods

[PID, photoionization detector; FID, flame ionization detector]

Parameter	Method
Water pH, specific conductance, temperature, dissolved oxygen	multi-probe electronic multimeter
Turbidity of water	optical turbidity meter
Total organic vapor and natural gases, including methane	field PID/FID, dynamic headspace
Floating oil >3-mm thickness on water	interface meter
Alkalinity of water	incremental titration

Table 3. Comparison of reporting limits for selected

aromatic volatile organic compounds by three methods

	Reporting limit in micrograms per liter		
Constituent	**USGS LS445**	**USGS LS1378**	**EPA8260[1]**
Benzene	0.026	0.1	1.0
Toluene	0.02	0.1	1.0
Ethyl benzene	0.036	0.1	1.0
m- and p-xylene	0.08	0.2	2.0
o-xylene	0.032	0.1	1.0

[1]Method used for Indiana Department of Environmental Management Mt. Vernon private well water sample analysis, January 2010

Table 4. Comparison of reporting limits for selected trace elements by two methods

	Reporting limit in micrograms per liter	
Constituent	**USGS LS2710**	**EPA6010B[1]**
Arsenic	0.03	10
Barium	0.07	2
Cadmium	0.016	2
Chromium	0.07	3
Selenium	0.03	30

[1]Method used for Indiana Department of Environmental Management Mt. Vernon private well water sample analysis, January 2010

Table 5. Quality control samples and parameter groups

Quality control sample	Number of samples[1]	Parameter groups[2]
Field blank	2	major ions, trace elements
Equipment blank	2	major ions, trace elements, VOCs
Trip blank	2	VOCs
Sequential duplicate	3	basic parameter group (3), optional parameter group (1)
Laboratory matrix-spike	3	VOCs (3), optional parameter group (1)
Blank source solution	1	trace elements, VOCs

[1] The number of samples for each QC type is based on a ratio of 1 field blank and 1 trip blank per field team and 2 field teams, 3 duplicates and matrix spikes per 30 water samples, and 1 inorganic and 1 organic blank source solution.
[2] The number of QC samples per parameter group is listed in parentheses.

Appendix 1. Parameter groups, constituent lists, and reporting limits

[RL, reporting limit; µg/L, microgram per liter; pCi/L, picoCurie per liter; mg/L, milligram per liter]

Major cations and anions	
Constituent	**RL (µg/L)**
Bromide	10
Calcium	22
Chloride	60
Fluoride	40
Iron	3
Magnesium	11
Manganese	0.2
Potassium	30
Silica	18
Sodium	60
Sulfate	90

Trace Elements	
Constituent	**RL (µg/L)**
Aluminum	2.2
Antimony	0.027
Arsenic	0.03
Barium	0.07
Beryllium	0.006
Boron	3.0
Cadmium	0.016
Chromium	0.07
Cobalt	0.021
Copper	0.8
Lead	0.025
Lithium	0.22
Manganese	0.13
Molybdenum	0.014
Nickel	0.09
Selenium	0.03
Silver	0.005
Strontium	0.2
Thallium	0.010
Uranium	0.004
Vanadium	0.08
Zinc	1.4

Aromatic volatile organic compounds	
Constituent	**RL (µg/L)**
tert-Butyl methyl ether	0.10
Benzene	0.026
Toluene	0.02
Ethylbenzene	0.036
m- and p-Xylene	0.08
o-Xylene	0.032
Isopropylbenzene	0.042
n-Propylbenzene	0.036
1,3,5-Trimethylbenzene	0.032
o-Ethyl toluene	0.032
tert-Butylbenzene	0.06
1,2,4-Trimethylbenzene	0.032
sec-Butylbenzene	0.034
4-Isopropyl-1-methylbenzene	0.06
1,2,3-Trimethylbenzene	0.06
Butylbenzene	0.08
1,2,3,5-Tetramethylbenzene	0.08
1,2,3,4-Tetramethylbenzene	0.10
Naphthalene	0.18

Polycyclic aromatic hydrocarbons	
Constituent	**RL (µg/L)**
1-Methylnaphthalene	1.0
2-Methylnaphthalene	1.0
Acenaphthene	1.0
Acenaphthylene	1.0
Anthracene	0.3
Benzo[a]anthracene	0.2
Benzo[a]pyrene	0.2
Benzo[b]fluoranthene	0.2
Benzo[g,h,i]perylene	0.2
Benzo[k]fluoranthene	0.1
Chrysene	0.2
Dibenz(a,h)anthracene	0.3
Fluoranthene	0.4
Fluorene	0.3
Indeno[1,2,3-cd]pyrene	0.2
Naphthalene	1.0
Phenanthrene	0.3
Pyrene	0.2

Dissolved natural gases	
Constituent	**RL (µg/L)**
Methane, ethane, ethene	3.0

Petroleum and oil	
Constituent	**RL (mg/L)**
Hexane extractable material (HEM)	5.0
Silica-gel-treated (SGT) HEM	5.0
Total petroleum hydrocarbons	0.25
Diesel range organics	0.25
Oil range organics	0.5

Radioactivity	
Constituent	**RL (pCi/L)**
Gross alpha	3.0
Gross beta	4.0

Appendix B: Posey County Invitation Letter and EI Fact Sheet

This fact sheet that will be provided to residents identified as potential EI participants. It will be sent to residents prior to the Exploratory Visit in an effort to identify participants. If residents do not respond, they will be contacted during the Exploratory Visit and, if they are not at their residence, the Fact Sheet will be left at the home.

FK reading level = 8.0

DATE

From: Bruce C. Tierney, M.D.
Agency for Toxic Substances and Disease Registry
4770 Buford Hwy, Mailstop F-59
Atlanta, GA 30341

To: ADD RECIPIENT'S ADDRESS

Re: ATSDR Posey County Private Well Water testing

Mr. or Ms. NAME:
There have been complaints by residents in your area about the quality of their private well water. Therefore, the Indiana Department of Environmental Management (IDEM) has asked the Agency for Toxic Substances and Disease Registry (ATSDR) to test water quality in the area. ATSDR is a federal health agency that works to protect the public from chemicals in the environment.

ATSDR is going to test private water wells in the area during the first week of June (June 4-8, 2012). We will be testing to see if there are chemicals in the water that may be a health concern for people. Your well has been identified by as one we might test.

A fact sheet is attached that provides information about our study, which is called an Exposure Investigation. If you want to be included or need more information, please call me, Dr. Bruce Tierney, at 770-488-0771 or at 1-888-320-5291. If I am not in, please leave a message and I will call you back.

ATSDR will be in the Posey County area from May 21-24, 2012 to talk to people about the testing.
Sincerely,

Bruce C. Tierney, M.D.
Exposure Investigation Team, ATSDR
770-488-0771 / 1-888-320-5291

Private Well Exposure Investigation, Posey County, Indiana
Agency for Toxic Substances and Disease Registry

Who are we?

- The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal agency that works to protect public health from chemicals in the environment.
- Our headquarters are in Atlanta, Georgia.
- We have a local office in Chicago.

Why are we here?

- We are here at the request of the Indiana Department of Environmental Management (IDEM).
- In 2008, residents in the area told IDEM that they had petroleum and salt in their private drinking water wells.
- In January 2010, IDEM tested water samples from 10 private drinking water wells in Posey County, near the city of Mount Vernon.
- Eight of the wells tested had petroleum or salt in the well water.
- IDEM asked ATSDR to see if petroleum and salt in the wells may be a health problem for people drinking private well water.
- ATSDR decided that an Exposure Investigation (EI) was needed.
- This EI will look to see if chemicals are in area private wells that may be a health problem.

Our Partners

- US Geological Survey (USGS)
- Indiana Department of Environmental Management (IDEM)
- US Environmental Protection Agency (USEPA)
- Indiana Division of Natural Resources (IDNR)

What will we do?

- As part of this EI, ATSDR and our partners will help IDEM test private well water in Posey County.
- We are testing the water for things that might be caused by nearby oil and gas wells.
- This testing will focus on a rural area in Posey County that has a high number of oil and gas wells.

How are we going to do this?	• The well water testing will include those already sampled by IDEM along with other private wells in the area. • If we determine your well water can be sampled, we might be asking you to let us test your well. ATSDR, IDEM and the USGS have put together a plan to sample wells and send them to a laboratory for testing. • To test your well water you must be the owner of the well, live on the property, and give us permission to test your well and ask you some questions.
What happens next?	• After we evaluate the test results, we will send you your results. • If we find chemicals that may be of health concern, we will recommend things you can do to lower exposure. We will give you contact information for additional information about what you can do to lower your risk.
When are we going to do this?	• ATSDR expects to complete the well testing by late Spring or early Summer, 2012.
Contact Information	• For additional information about this exposure investigation contact Dr. Bruce Tierney with the ATSDR Exposure Investigation Team at 770-488-0771 or toll free at 1-888-320-5291 or by email at BTierney@cdc.gov. • For additional information about ATSDR see: http://www.atsdr.cdc.gov

Appendix C: Consent Form

US Department of Health and Human Services (DHHS)
Agency for Toxic Substances and Disease Registry (ATSDR)
Posey County, Indiana Private Well Drinking Water Quality Exposure Investigation (EI)
Adult Consent Form

Who are we and why we are doing this EI?

- The Indiana Department of Environmental Management (IDEM) asked ATSDR to test private well in the area to look for contamination.
- The Agency for Toxic Substances and Disease Registry (ATSDR), ATSDR is a federal health agency that works to protect the public from chemicals in the environment.
- The US Geological Survey (USGS) and IDEM are helping ATSDR with sampling and testing
- ATSDR is inviting you to have your well water tested for contaminants such as salt, metals, and other chemicals, such as benzene

Location for the testing

- We will test your well you use for drinking water.
- We will take tap water samples. If you have one, we will take samples before your treatment system.

What does this involve?

We would like you to volunteer to be part of this project.

We need your written permission to test your well and ask you some questions.

This will take about an hour of your time.

Private Well Water Testing:

- We will take samples of your well water and put it into specially prepared bottles. This will take about an hour.
- As we are filling the bottles with water, we will test the water for things like temperature.
- The bottles will be sent to a laboratory to test for chemicals. These tests include salt, metals and other chemicals, such as benzene.
- We will collect water from spigot that provides water directly from your well or, when necessary, from the well itself.

Answering Questions:

- We will ask you questions about your water, well history, any water softening or treatment, and if you know of any petroleum wells nearby. The questions will take about 20 minutes to complete.

Test Results:

- ATSDR will mail you the test results and tell you what the results mean to you and your family.
- We will be available to answer any questions you have about the results.
- We are testing water that is taken directly from your private water well before it has been softened or filtered. If you soften or filter your water and the testing finds chemicals in your well water, we will recommend that you have your tap water tested.
- The additional testing of your tap water is your choice and is not part of our Exposure Investigation so you will be responsible to pay for it.

When will I get my results?	• You will get your test results by mail about 10-12 weeks after sampling. ATSDR will be available by phone to explain your results.
What are the benefits from being in this EI?	• You will find out if your water contains chemicals that might be harmful to you and your family. • If we find chemicals that may be of concern for your health, we will recommend things you can do to reduce the risk of coming in contact with the chemicals. • Test results will not tell you if you might get sick from these chemicals in the future.

What are the risks of this EI?	• There are no risks to you or your family from having your well tested as part of this EI. • You might be inconvenienced. It will take about 60 minutes for us to ask you questions and collect your well water. We may need to run water from the well for a brief period of time which might leave a large wet area in your yard. • If you have a treatment system, we may need to get the water sample directly from the well. We might need to turn off your well for a short period of time while we take samples.
What if I have questions?	• If you have any questions about this testing, you can ask us now. • If you have questions later, you can call **Dr. Bruce Tierney at 770-488-0771.** • Or call the ATSDR **toll free number** 1-888-320-5291**.**
What about privacy?	• We will protect your privacy as much as the law allows. • We will give you an identification (ID) number. • This ID number, not your name, will go on the water sample sent to the laboratory. • We will not use your name in any report we write. • We will keep a record of your name, address and ID number so that we can send you the water test results. ATSDR will keep your personal information in a password protected computer. Copies of your consent form will be kept in a locked file cabinet. • Your name and address will be deleted from our files after our report is finalized (up to 3 years). • Information given to the state of Indiana must be made public if someone asks them for the information. • If you give us permission, we will share information about your well water with other Indiana state and federal environmental and public health agencies as needed so they can make informed public health decisions. • By signing this consent form, you are agreeing to let us share your well water results with other agencies if needed. If you initial "yes" to the statement above your signature you will also be agreeing to share your personal information with other Indiana state and federal environmental and public health agencies, if needed, in order for them to make informed public health decisions. • After the final report is written all personal information will be destroyed by ATSDR.

Voluntary Consent

- I am at least 18 years of age.
- I am the property owner.
- I agree to have my private well tested by ATSDR.
- I agree to answer the questions that ATSDR will ask me about my private well and water use.
- I agree to have my well water test results shared with other Indiana state and federal environmental and public health agencies, if needed. My personal information will not be shared with other agencies without my consent.
- I have been given the chance to ask questions. I know that having my well tested is my choice and voluntary.
- I will be given a copy of this form to keep.
- I know that even though I have agreed to this testing and answering question that I can change my mind at any time without penalty.

Signature

May we share your personal information with other federal or Indiana state health and environmental agencies, if needed, in order to make informed public health decisions (You may check "NO" and still participate in this investigation)? If this information is shared with other Indiana state and federal environmental and public health agencies, they will also protect your privacy to the extent that the law allows (check one).

YES__________, NO_________

I have read this form or it has been read to me. I give my permission to have my well water tested and to answer the questions ATSDR asks me.

_____________________________________ ____________________

Signature of Person Given Consent Date

____

Printed Name of Person Given Consent

Age __________

Street Address (If this address has another defining number or letter, please provide that now):

____

____

____

Mailing Address (If different from Street Address):

____

____

____

Telephone___________________ Cell phone __________________

Email Address: ________________________________

Certification of Consent Form Administrator:

I have read the consent form to the person name above. They have had the opportunity to ask questions about the EI and had the questions answered.

_____________________________________ ____________
Signature of person administering consent Date

____
Printed Name of person administering consent

Appendix D: Questionnaire

Questionnaire for the Posey County Exposure Investigation

Flesch-Kincaid Grade Level: 8.0 (with agency names)

OMB #0923-0040

Name of Surveyor: Date:

I just want to repeat my name is #######. Now since we have your permission, we would now like to ask you some questions.

Water History:

1. What is the main source of drinking water in your home?
   - ☐ Private Well
   - ☐ City or County (public)
   - ☐ Spring
   - ☐ Pond
   - ☐ Cistern
   - ☐ Community Well
   - ☐ Bottled
   - ☐ Other: (specify)
   - ☐ Don't know
   - ☐ Refused

2. Has the water from your private well ever been tested?
   - ☐ Yes
   - ☐ No
   - ☐ Don't know
   - ☐ Refused

3. If “yes” do you know the date it was tested who did the testing, whether it was tested for bacterial and/or chemical contamination, and the results?

____
____
____
____
____

4. What is your main source of water for cooking?
   - ■ Private Well
   - ■ City or County (public)
   - ■ Spring
   - ■ Pond
   - ■ Cistern
   - ■ Community Well
   - ■ Bottled
   - ■ Other: (specify)
   - ■ Don’t know
   - ■ Refused

5. What is the main source of water for bathing and showering?
   - ■ Private Well
   - ■ City or County (public)
   - ■ Spring
   - ■ Pond
   - ■ Cistern
   - ■ Community Well
   - ■ Bottled
   - ■

- Other: (specify)
- Don't know
- Refused

6. What is the main source of water for pools and/or hot tubs (to include "kiddie" or wading pools)?
    - Private Well
    - City or County (public)
    - Spring
    - Pond
    - Cistern
    - Community Well
    - Bottled
    - Other: (specify)
    - Don't know
    - Refused

7. List all of the water treatment devices for your drinking water or water used for mixing drinks (e.g. baby formula, juices)
    - None
    - Charcoal Filter/Granular Activated
    - Ceramic Filter
    - Reverse Osmosis
    - Water Softener
    - Distillation
    - Sediment Filter
    -

Aerator

- Water Filter system (e.g. Brita, Pur, etc.)
- Iron Removal System
- Chlorinator
- Don’t know
- Refused

8. List all of the water treatment devices for your water used for cooking.

- None
- Boil water
- Charcoal Filter/Granular Activated
- Ceramic Filter
- Reverse Osmosis
- Water Softener
- Distillation
- Sediment Filter
- Aerator
- Water Filter system (e.g. Brita, Pur, etc.)
- Iron Removal System
- Chlorinator
- Don’t know
- Refused

9. List all of the water treatment devices for your bathing and showering water.

- None
-

- Charcoal Filter/Granular Activated
- Ceramic Filter
- Reverse Osmosis
- Water Softener
- Boil water
- Distillation
- Sediment Filter
- Aerator
- Water Filter system (e.g. Brita, Pur, etc.)
- Iron Removal System
- Chlorinator
- Don’t know
- Refused

10. If you use filters, do you maintain them according to the manufacturers recommendations or if you have a whole house filter do you have a contractor maintain them?
    - Yes
    - No
    - Don’t know
    - Refused

11. If you use a Water Softener, do you regularly maintain it?
    - Yes
    - No
    - Don’t know
    - Refused

12. If yes, what is the brand and age of the Water Softener?

- Brand: ____
- Age: ____
- Don't know
- Refused

13. Is there anything you want us to know that we did not ask such as:
    a. Do you know the depth of your water well or have any records of the well history of your private water well?

    - Yes
    - No
    - Don’t know
    - Refused

    b. If yes, please provide details (type, age, depth of well)

____
____
____
____
____
____

General Information:

1. First name (please spell): ______________________________
2. Last name (please spell): ______________________________
3. Middle initial: __________________
4. How long have you lived at this address?
   - < 1 year
   - 1-10 years
   - >10 years
   - Don’t know
   - Refused

Demographic Information:

1. Gender ______

2. Age at time of survey _____ Refused

3. Ethnicity Data Standard – Are you Hispanic, Latino/a, or Spanish origin? (One or more categories may be selected)

- No, not of Hispanic, Latino/a, or Spanish origin
- Yes, Mexican, Mexican American, Chicano/a
- Yes, Puerto Rican
- Yes, Cuban
- Yes, Another Hispanic, Latino/a or Spanish origin
- Refused

4. Race Data Standard – What is your race? (One or more categories may be selected)

- White
- Black or African American
- American Indian or Alaskan Native
- Asian American
- Chinese
- Filipino
- Japanese
- Korean
- Vietnamese
- Other Asian
- Native Hawaiian
- Guamanian or Chamorro
- Samoan
- Other Pacific Islander
- Refused

5. How many people live here fulltime? ________ (if more than 1 person complete General Information question 4 and Demographic Information for each resident)

NOTE: Surveyor/Sampling team will also consult with home owner to diagram the location of the residence water supply well, residence septic system, residence home heating oil tank, and the wells, septic system, and tanks on nearby residences, other fuel storage tanks, abandoned water supply wells, old boreholes, oil wells or injection wells on the property and in the immediate vicinity of the water supply well (1 to 2 acre area?). They also will note the existence and approximate location of wells and boreholes that are located on the property but that are not in the immediate vicinity of the water supply well.

Appendix E: Lists of Chemical Abstract Service Number, USGS Reporting Limits, Comparison Values, EPA Water Quality Values and Regional Screening Levels for Sampled Parameters

Table E.1
Lists of Chemical Abstract Service Number, USGS Reporting Limits, Comparison Values, EPA Water Quality Values and Regional Screening Levels for Major Ions

Ion	CAS Number	USGS Reporting Limit (ug/L)	CV (ug/L)[a]	EPA Values (ug/L)[b]	RSL (ug/L)[c]
Bromide	7726-95-6	10	NR	NR	NR
Calcium	7789-78-8	22	NR	NR	NR
Chloride	16887-00-6	60	NR	250000 (SMCL)	NR
Fluoride	7681-49-4	40	NR	4000 (MCL); 2000 (SMCL)	620 (n)
Iron	8053-60-9	3	NR	300 (SMCL)	11000 (n)
Magnesium	7439-95-4	11	NR	NR	NR
Manganese	8075-39-6	0.2	500 (RMEG Child)	50 (SMCL); 300 (LTHA)	320 (n)
Potassium	7440-09-7	30	NR	NR	NR
Silica	99439-28-8	18	NR	NR	NR
Sodium	7646-69-7	60	NR	20,000 (HBV)	NR
Sulfate	18785-72-3	90	NR	250000 (SMCL)	NR

[a] - ATSDR's Comparison Values (CV) – available 2/29/2012
[b] – EPA Values available from EPA's *2011 Edition of the Drinking Water Standards and Health Advisories*
[c] – Regional Screening Levels (RSLs) from EPA - online 2/29/2012
CAS Chemical Abstracts Service
USGS US Geological Survey
NR Not Reported
RMEG Reference Dose Media Evaluation Guide
MCL Maximum Contaminant Level
SMCL Secondary MCL (based on cosmetic or aesthetic effects)
HBV Health Based Value - Drinking Water Advisory
LTHA Lifetime Health Advisory

(n) RSL is based on non-cancer endpoint

(c) RSL is based on cancer endpoint

Table E.2
Lists of Chemical Abstract Service Number, USGS Reporting Limits, Comparison Values, EPA Water Quality Values and Regional Screening Levels for Trace Elements

Trace Element	CAS Number	USGS Reporting Limit (ug/L)	CV (ug/L)[a]	EPA Values (ug/L)[b]	RSL (ug/L)[c]
Aluminum	7429-90-5	2.2	10,000 (chronic EMEG Child)	50 to 200 (SMCL)	16000 (n)
Antimony	7440-36-0	0.027	4 (RMEG Child)	6 (MCL)	6 (n)
Arsenic	7440-38-2	0.03	0.02 (CREG)	10 (MCL)	0.045 (c)
Barium	7440-39-3	0.07	2000 (Chronic EMEG Child)	2000 (MCL)	2900 (n)
Beryllium	7440-41-7	0.006	20 (Chronic EMEG Child)	4 (MCL)	16 (n)
Boron	7440-42-8	3	2000 (EMEG/RMEG Child)	6000 (LTHA)	3100 (n)
Cadmium	7440-43-9	0.016	1 (Chronic EMEG Child)	5 (MCL)	6.9 (n)
Chromium	7440-47-3	0.07	10 (Chronic EMEG Child)[d]	100 (MCL)	16000 (n) for Cr (III); 0.031 (c) for Cr (VI)
Cobalt	7440-48-4	0.021	100 (Intermed EMEG Child)	NR	4.7 (n)
Copper	7440-50-8	0.8	100 (Intermed EMEG Child)	1300 (Action Level); 1000 (SMCL)	620 (n)
Lead	7439-92-1	0.025	NR	15 (Action Level)	NR
Lithium	7439-93-2	0.22	NR	NR	31 (n)
Magnesium	7439-95-4	0.13	NR	NR	NR
Molybdenum	7439-98-7	0.014	50 (RMEG Child)	40 (LTHA)	78 (n)
Nickel	7440-02-0	0.09	NR	100 (LTHA)	300 (n)
Selenium	7782-49-2	0.03	50 (Chronic EMEG Child)	50 (MCL)	78 (n)
Silver	7440-22-4	0.005	50 (RMEG Child)	100 (SMCL)	71 (n)
Strontium	7440-24-6	0.2	6000 (RMEG Child)	4000 (LTHA)	9300 (n)
Thallium	7440-28-0	0.01	NR	2 (MCL)	0.16 (n)
Uranium	12070-09-6	0.004	2 (Intermed EMEG Child)	30 (MCL)	47 (n)
Vanadium	7440-62-2	0.08	100 (Intermed EMEG Child)	NR	78 (n)
Zinc	7440-66-6	1.4	3000 (Chronic EMEG Child)	5000 (SMCL)	4700 (n)

[a] - ATSDR's Comparison Values (CV) – available 2/29/2012
[b] – EPA Values available from EPA's *2011 Edition of the Drinking Water Standards and Health Advisories*
[c] – Regional Screening Levels (RSLs) from EPA - online 2/29/2012
[d] – Value is for hexavalent chromium
CAS Chemical Abstracts Service
USGS US Geological Survey
NR Not Reported
EMEG Environmental Media Evaluation Guide
RMEG Reference Dose Media Evaluation Guide
CREG Cancer Risk Guide
Intermed Intermediate Duration

SMCL Secondary Maximum Contaminant Level (based on cosmetic or aesthetic effects)
LTHA Lifetime Health Advisory

(n) RSL is based on non-cancer endpoint

(c) RSL is based on cancer endpoint

Table E.3
Lists of Chemical Abstract Service Number, USGS Reporting Limits, Comparison Values, EPA Water Quality Values and Regional Screening Levels for Volatile Organic Compounds

VOC	CAS Number	USGS Reporting Limit (ug/L)	CV (ug/L)[a]	EPA Value (ug/L)[b]	RSL (ug/L)[c]
tert-Butyl methyl ether	1634-04-4	0.1	3000 (Intermed EMEG Child)	NR	12 (c)
Benzene	71-43-2	0.026	0.6 (CREG)	5 (MCL)	0.39 (c)
Toluene	108-88-3	0.02	200 (Intermed EMEG Child)	1000 (MCL)	860 (n)
Ethylbenzene	100-41-4	0.036	1000 (RMEG Child)	700 (MCL)	1.3 (c)
m- and p- Xylene	NA	0.08	2000 (Chronic EMEG Child for total xylenes)	10,000 (MCL)	190 (n)
o-Xylene	95-47-6	0.032	2000 (Chronic EMEG Child for total xylenes)	10,000 (MCL)	190 (n)
Isopropylbenzene	98-82-8	0.042	1000 (RMEG Child)	NR	390 (n)
n-Propylbenzene	103-65-1	0.036	NR	NR	530 (n)
1,3,5-Trimethylbenzene	108-67-8	0.032	NR	NR	87 (n)
o-Ethyl toluene	611-14-3	0.032	NR	NR	NR
tert-Butylbenzene	98-06-6	0.06	NR	NR	NR
1,2,4-Trimethylbenzene	95-63-6	0.032	NR	NR	15 (n)
sec-Butylbenzene	135-98-8	0.034	NR	NR	NR
4-Isopropyl-1-methylbenzene	99-87-6	0.06	NR	NR	NR
1,2,3-Trimethylbenzene	526-73-8	0.06	NR	NR	10 (n)
Butylbenzene	104-51-8	0.08	NR	NR	780 (n)
1,2,3,5-Tetramethylbenzene	527-53-7	0.08	NR	NR	NR
1,2,3,4-Tetramethylbenzene	488-23-3	0.1	NR	NR	NR
Naphthalene	91-20-3	0.18	200 (RMEG Child)	100 (LTHA)	0.14 (c)

[a] - ATSDR's Comparison Values (CV) – available 2/29/2012
[b] – EPA Values available from EPA's *2011 Edition of the Drinking Water Standards and Health Advisories*
[c] – Regional Screening Levels (RSLs) from EPA - online 2/29/2012
CAS Chemical Abstracts Service
VOC Volatile Organic Compound
USGS US Geological Survey
NR Not Reported
EMEG Environmental Media Evaluation Guide

RMEG Reference Dose Media Evaluation Guide
CREG Cancer Risk Guide
Intermed Intermediate Duration

SMCL Secondary Maximum Contaminant Level (based on cosmetic or aesthetic effects)
LTHA Lifetime Health Advisory
(n) RSL is based on non-cancer endpoint
(c) RSL is based on cancer endpoint

Table E.4
Lists of Chemical Abstract Service Number, USGS Reporting Limits, Comparison Values, EPA Water Quality Values and Regional Screening Levels for Polycyclic Aromatic Hydrocarbons

PAH	CAS Number	USGS Reporting Limit (ug/L)	CV (ug/L)	EPA Value (ug/L)	RSL (ug/L)
1-Methylnaphthalene	90-12-0	1	700 (Chronic EMEG Child)	NR	0.97 (c)
2-Methylnaphthalene	91-57-6	1	40 (RMEG Child)	NR	27 (n)
Acenaphthene	83-32-9	1	600 (RMEG Child)	NR	400 (n)
Acenaphthylene	208-96-8	1	NR	NR	NR
Anthracene	120-12-7	0.3	3000 (RMEG Child)	NR	1300 (n)
Benzo(a)anthracene	56-55-3	0.2	NR	NR	0.029 (c)
Benzo(a)pyrene	50-32-8	0.2	0.005 (CREG)	0.2 (MCL)	0.0029 (c)
Benzo(b)fluoranthene	205-99-2	0.2	NR	NR	0.029 (c)
Benzo(g,h,i)perylene	191-24-2	0.2	NR	NR	NR
Benzo(k)fluoranthene	207-08-9	0.1	NR	NR	0.29 (c)
Chrysene	218-01-9	0.2	NR	NR	2.9 (c)
Dibenzo(a,h)anthracene	53-70-3	0.3	NR	NR	0.0029 (c)
Fluoranthene	206-44-0	0.4	400 (RMEG Child)	NR	630 (n)
Fluorene	86-73-7	0.3	400 (RMEG Child)	NR	220 (n)
Indeno(1,2,3-cd)pyrene	193-39-5	0.2	NR	NR	0.029 (c)
Naphthalene	91-20-3	1	200 (RMEG Child)	100 (LTHA)	0.14 (c)
Phenanthrene	85-01-8	0.3	NR	NR	NR
Pyrene	129-00-0	0.2	300 (RMEG Child)	NR	87 (n)

[a] - ATSDR's Comparison Values (CV) – available 2/29/2012
[b] – EPA Values available from EPA's *2011 Edition of the Drinking Water Standards and Health Advisories*
[c] – Regional Screening Levels (RSLs) from EPA - online 2/29/2012
CAS Chemical Abstracts Service
PAH Polycyclic Aromatic Hydrocarbon
USGS US Geological Survey
NR Not Reported
EMEG Environmental Media Evaluation Guide
RMEG Reference Dose Media Evaluation Guide
CREG Cancer Risk Guide

(n) RSL is based on non-cancer endpoint

(c) RSL is based on cancer endpoint

Appendix F: Individual Results Letter

(ATSDR Letterhead)

Date

Dear NAME:

In June 2012 you allowed the Agency for Toxic Substances and Disease Registry (ATSDR) to take samples of your private well water and test them for chemicals. We are providing you with the test results in this letter. We are also providing you what we think the results mean for people using this water for drinking and other purposes. We thank you for allowing us to test your well. If you have any questions, please call or e-mail Dr. Bruce Tierney at 770-488-0771, bgt2@cdc.gov.

Sincerely,
Bruce Tierney, MD
ATSDR Division of Community Health Investigations
Exposure Investigations Team

Enclosures

Appendix C: Results of Data Comparison

The first step in the data evaluation process is to compare detected concentrations of contaminants to health-based comparison levels. Concentrations of contaminants below the comparison level are not likely to result in health effects. Contaminants found at concentrations above the comparison level are further evaluated.

Comparison levels are ideally based on health effects. ATSDR's preferred source for comparison levels are ATSDR Comparison Values (CVs) that are based on health effects. If ATSDR CVs are not available, appropriate US EPA, IDEM and US DOI comparison levels were used[6].

EPA's Maximum Contaminant Levels (MCLs) are enforceable values used to regulate public water systems. They do not apply to private wells, but were used if no other comparison levels were available. Secondary MCLs (SMCLs) are not based on health effects but on an unpleasant taste, smell or color. SMCLs provide values that assess general water quality, including total dissolved solids and pH.

Comparison levels are not available for several chemicals: four ions (calcium, magnesium, potassium, silica), four VOCs (1,2,3,4- and 1,2,3,5-tetramethylbenzene, 2-ethyltoluene, 4-isopropyltoluene), three PAHs (acenaphthene, benzo(g,h,i)perylene, phenanthrene) and several petroleum components (ethane, ethene, oil and grease, petroleum hydrocarbons). The ions listed above that lack comparison levels are not expected to result in health effects because these metals are not expected to cause harmful health effects. The VOCs, PAHs, ethene and petroleum hydrocarbons listed above were not detected in water during the sampling, therefore, a comparison would not have been completed.

Ethane gas was detected in 9/10 samples and oil and grease were detected in 10/10 samples. Ethane gas is found in natural gas and is a byproduct of petroleum refining. Oil and grease are associated with oil production. Neither ethane nor oil and grease should be present in drinking water. Their presence, along with the presence of methane and TPH, are indicative of poor water quality.

Table C.1 provides the maximum concentration detected and the comparison level for all contaminants that were detected in private well water results obtained as part of the EI.

6 Values not formerly reviewed or endorsed by ATSDR.

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Water Quality Indicators					
Analyzed at the home during the sampling					
pH	**pH of 8.84**	**Measured in all samples**	**6.5-8.5 (SMCL[1]: low pH – bitter metallic taste and corrosion; high pH – slippery feel, soda taste, deposits)**	**2/29**	**Yes - Effects water quality**
Specific conductance	2,896 µS/cm	Measured in all samples	NA	NA	NA
Dissolved oxygen	6.02 mg/L	Measured in all samples	NA	NA	NA
Water temperature	21.29 °Celsius	Measured in all samples	NA	NA	NA
Turbidity	10.8 turbidity ratio units	Measured in all samples	NA	NA	NA
Field observation of gas bubbles in sample	**--**	**NA**	**NA**	**12/29**	**Yes - Indicator of water quality**
Field observation of petroleum odor in sample	**--**	**NA**	**NA**	**9/29**	**Yes - Indicator of water quality**
Analyzed in the laboratory					
pH	**pH of 8.90**	**Measured**	**6.5-8.5 (SMCL[1]:**	**2/29**	**Yes - Effects**

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
		in all samples	**low pH – bitter metallic taste and corrosion; high pH – slippery feel, soda taste, deposits)**		**water quality**

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Specific conductance	2,910 µS/cm	Measured in all samples	NA	NA	NA
Major Ions (mg/L)					
Total Dissolved Solids (TDS)	**1750**	**Measured in all samples**	**500 (SMCL[1] – colored water and staining, salty taste, hardness)**	**24/29**	**Yes - Effects water quality**
Calcium	183	29/29	NA	0/29	No comparison level
Magnesium	89.6	29/29	NA	0/29	No comparison level
Potassium	2.78	29/29	NA	0/29	No comparison level
Sodium	**680**	**29/29**	**20 (US EPA – for salt-sensitive people)**	**26/29**	**Yes**
Bromide	1.9	18/29	2 (WHO)	0/18	No
Chloride	**705**	**29/29**	**250 (SMCL[1] – salty taste)**	**5/29**	**Yes**
Silica	33.7	29/29	NA	0/29	No comparison level
Sulfate	65.4	16/29	250 (SMCL[1] – salty taste)	0/16	No

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Elements (ug/L)[2]					
Aluminum	13.6	4/29	10,000/40,000 (Child/Adult Chronic EMEG)/50 to 200 (SMCL[1] – discoloration)	0/4	No
Barium	868	29/29	2,000/7,000 (Child/Adult Chronic EMEG)/2,000 (MCL)	0/29	No
Beryllium	0.038	24/29	20/70 (Child/Adult Chronic EMEG)/4 (MCL)	0/24	No
Cadmium	0.042	4/29	1/3.5 (Child/Adult Chronic EMEG)/5 (MCL)	0/4	No
Chromium	0.64	7/29	9/32 (Child/Adult Chronic EMEG) (value for Cr VI)/100 (MCL)	0/7	No
Cobalt	1.06	27/29	100/350 (Child/Child Intermediate EMEG)	0/27	No
Copper	10.2	8/29	100/350	0/8	No

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
			(Child/Adult Intermediate EMEG)/1,000 (SMCL[1] – blue-green staining; metallic taste)		

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Iron	**1,400**	**29/29**	**300 (SMCL[1] – rusty color, metallic taste and red-orange staining)**	**9/29**	**Yes**
Lead	0.504	22/29	15 (MCL)	0/22	No
Lithium	**56.3**	**29/29**	**31 (RSL)**	**4/29**	**Yes**
Manganese	**803**	**29/29**	**500/1,800 (Child/Adult RMEG)/50 (SMCL[1] – black staining; bitter, metallic taste)**	**2/29 (health-based)/5/29 (SMCL)**	**Yes**
Molybdenum	5.51	29/29	50/180 (Child/Adult RMEG)	0/29	No
Nickel	2	19/29	200/700 (Child/Adult RMEG)	0/19	No
Silver	0.025	1/29	50/180 (Child/Adult RMEG)/100 (SMCL[1] – skin discoloration; graying of white part of eye)	0/1	No
Strontium	1290	29/29	6,000/21,000 (Child/Adult RMEG)	0/29	No
Thallium	0.071	3/29	2 (MCL)	0/3	No
Vanadium	0.56	18/29	100/350	0/18	No

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
			(Child/Adult Intermediate EMEG)		
Zinc	237	20/29	3,000/11,000 (Child/Adult Chronic EMEG)/5,000 (SMCL[1] – metallic taste)	0/20	No
Antimony	0.758	4/29	4/10 (Child/Adult RMEG)/6 (MCL)	0/4	No
Arsenic[3]	**8**	**23/29**	**0.02 (CREG), 3/11 (Child/Adult Chronic EMEG)/10 (MCL)**	**23/23(health-based)/ (0/23 MCL)**	**Yes**
Boron	1240	29/29	2,000/7,000 (Child/Adult EMEG/RMEG)	0/29	No
Selenium	1.5	8/29	50/180 (Child/Adult chronic EMEG)/50 (MCL)	0/8	No
Uranium (natural)	**10**	**16/29**	**2/7 (Child/Adult Intermediate EMEG)/30 (MCL)**	**5/16 (health-based)/ 0/16 (MCL)**	**Yes**
Volatile Organic Compounds (VOCs) (ug/L)					

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
1,2-Dichloro-ethane	ND	0/29	0.4 (CREG)/5 (MCL)	NA	No
1,2,3,4-Tetramethylbenzene	ND	0/29	NA	NA	No comparison level
1,2,3,5-Tetramethylbenzene	ND	0/29	NA	NA	No comparison level
1,2,3-Trimethyl-benzene	ND	0/29	10 (RSL)	NA	No
1,2,4-Trimethyl-benzene	ND	0/29	15 (RSL)	NA	No
1,3,5-Trimethyl-benzene	ND	0/29	87 (RSL)	NA	No
2-Ethyl-toluene	ND	0/29	NA	NA	No comparison level
4-Isopropyl-toluene	ND	0/29	NA	NA	No comparison level
Acetone	2	4/29	9,000/32,000 (Child/Adult RMEG)	0/4	No
Benzene	ND	0/29	0.6 (CREG)/5 (MCL)	NA	No
Ethyl Methyl Ketone	7.3	4/29	6,000/21,000 (Child/Adult RMEG)	0/4	No
Ethylbenzene	0.037	1/29	1,000/3,500 (Child/Adult RMEG)/700 (MCL)	0/1	No

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Isopropylbenzene	ND	0/29	1,000/3,500 (Child/Adult RMEG)	NA	No
Methyl tert-butyl ether	ND	0/29	3,000/11,000 (Child/Adult Intermediate EMEG)	NA	No
m-Xylene plus p-xylene	0.14	2/29	2,000/7,000 (Child/Adult chronic EMEG)/10,000 (MCL)	0/2	No
Naphthalene	ND	0/29	200/700 (Child/Adult RMEG)	NA	No
n-Butylbenzene	ND	0/29	780 (RSL)	NA	No
n-Propylbenzene	ND	0/29	530 (RSL)	NA	No
Carbon Disulfide	0.23	3/29	1,000/3,500 (Child/Adult RMEG)	0/3	No
o-Xylene	0.044	1/29	2,000/7,000 (Child/Adult chronic EMEG)/10,000 (MCL)	0/1	No
Sec-Butylbenzene	ND	0/29	160 (RSL)	NA	No
Styrene	ND	0/29	100 (LTHA)	NA	No
Tert-Butylbenzene	ND	0/29	51 (RSL)	NA	No
Toluene	0.02	1/29	200/700	0/1	No

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
	(estimated)		(Child/Adult Intermediate EMEG)/1000 (MCL)		

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Polycyclic Aromatic Hydrocarbons (PAHs) (ug/L)					
Fluorene	ND	0/29	400/1,400 (Child/Adult RMEG)	NA	No
Acenaphthene	ND	0/29	600/2,100 (Child/Adult RMEG)	NA	No
Acenaphthylene	ND	0/29	NA	NA	No comparison level
Anthracene	ND	0/29	3,000/11,000 (Child/Adult RMEG)	NA	No
1-Methylnaphthalene	ND	0/29	700/2,500 (Child/Adult Chronic EMEG)	NA	No
2-Methylnaphthalene	ND	0/29	400/1,400 (Child/Adult Chronic EMEG)	NA	No
Benzo[a]anthracene	ND	0/29	0.029 (RSL)	NA	No
Benzo[a]pyrene[3]	ND	0/29	0.0048 (CREG)	NA	No
Benzo[b]fluoranthene	ND	0/29	0.029 (RSL)	NA	No
Benzo[ghi]perylene	ND	0/29	NA	NA	No comparison level
Benzo[k]fluoranthene	ND	0/29	0.29 (RSL)	NA	No
Chrysene	ND	0/29	2.9 (RSL)	NA	No

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
Dibenzo[a,h] anthracene	ND	0/29	0.0029 (RSL)	NA	No
Phenanthrene	ND	0/29	NA	NA	No comparison level
Pyrene	ND	0/29	300/1,100 (Child/Adult RMEG)	NA	No
Fluoranthene	ND	0/29	400/1,400 (Child/Adult RMEG)	NA	No
Indeno[1,2,3-cd]pyrene	ND	0/29	0.029 (RSL)	NA	No
Radiation (pCi/L)					
Alpha radiation, 30 day recount	**15**	**26/26**[4]	**15 (MCL)**	**1/26**	**Yes**
Alpha radiation, 3 day count	**31.6**	**25/26**[4]	**15 (MCL)**	**3/25**	**Yes**
Beta radiation, 30 day recount	8.1	26/26[4]	50 (SV)	0/26	No
Beta radiation, 3 day count	4.83	24/26[4]	50 (SV)	0/24	No
Total Petroleum Hydrocarbon (TPH)/oil and grease/gases (ug/L except as noted)					
Diesel range organic (DRO) compounds	930	8/10	NA	NA	--
Motor oil range organic (MRO)	170	7/10	NA	NA	--

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**
compounds					
Addition of DRO and MRO compounds	**1100**	**8/10**	**260 (IDEM RISC)**	**7/8**	**Yes**
Ethane	9.1	9/10	NA	NA	No comparison level
Ethene	ND	0/10	NA	NA	No comparison level
Methane (mg/L)	**24**	**10/10**	**10 (DOI - Action Level)**	**6/10**	**Yes**
Oil and grease	4.5 (estimated)	10/10	NA	NA	No comparison level
Petroleum hydrocarbons	ND	0/10	NA	NA	No comparison

No Tentatively Identified Compounds (TICs) for Semivolatile Organic Compounds (SVOCs) were detected.

ND Contaminant not detected in any sample
µS/cm microsiemens per centimeter
mg/L milligram per liter of water
µg/L microgram per liter of water
pCi/L picocuries per liter of water
ºC degrees Celsius
< (value) chemical was not found in the sample at the method detection limit
estimated the laboratory identified the value as an estimate based on sample conditions
CV Comparison Value (CV) from ATSDR – online in Sequoia database
NA Comparison Level Not Available
IOM Institute of Medicine
ATSDR Agency for Toxic Substances and Disease Registry
US EPA US Environmental Protection Agency
MCL Maximum Contaminant Level (EPA value)
SMCL Secondary Maximum Contaminant Level (EPA value)
IDEM RISC Indiana Department of Environmental Management – Risk Integrated System of Closure
DOI US Department of the Interior – Action Level
DRO Diesel Range Organic compounds
MRO Motor Range Organic compounds
WHO World Health Organization

Table C.1: Comparison of Posey County Water Data					
Contaminant	**Maximum in Water**	**Frequency of Detection**	**Comparison Level**	**Frequency of Exceedance**	**Contaminant of Concern?**

EMEG Environmental Media Evaluation Guide (ATSDR CV)
RSL US EPA's Regional Screening Level
LTHA Lifetime Health Advisory (EPA value)
RMEG Reference Dose Media Evaluation Guide (ATSDR CV)
CREG Cancer Risk Evaluation Guide (ATSDR CV)

[1] Basis for SMCL values provided in http://water.epa.gov/drink/contaminants/secondarystandards.cfm

[2] All elements were evaluated using filtered samples.

[3] Reporting limits (RLs) are provided in the protocol (Appendix B). RLs were chosen to ensure that they were at or below the comparison level used to evaluate the results, where available. The only RLs below the comparison level was for benzo(a)pyrene (RL = 0.2 µg/L and comparison level = 0.005 µg/L) and arsenic (RL = 0.03 µg/L and comparison level = 0.02 µg/L). Benzo(a)pyrene was not detected in any of the test samples.

[4]Samples were not analyzed for radiation in three locations, therefore, the total number of sampled locations was 26.

Appendix D: Dose Calculations

The health evaluation includes deriving an exposure dose (e.g., the dose of contaminant that a person is exposed to daily) and using a toxicity factor to determine whether health effects may result from exposure.

Exposure doses are calculated for ingestion of water by appropriate receptors using assumptions of how often they contact the site contaminants. The exposure equation used to evaluate ingestion of water is:

$$D = \frac{C * IR * EF}{BW}$$

where,

D = exposure dose (mg/kg-day)

C = contaminant concentration in water (mg/L)

IR = ingestion rate of contaminated water (L/day)

EF = exposure factor (unitless)

BW = body weight (kg)

Exposure doses are derived to assess both noncarcinogenic and carcinogenic effects using the above equation and exposure factors (e.g., body weight, water intake) provided in the US EPA Exposure Factors Handbook (EFH) (USEPA 2011a). For noncarcinogenic effects, a child receptor (birth to < 1 year) was used to evaluate potential health effects because this age interval represents the most highly exposed receptor. The dose for the noncancer assessment is calculated for the period of exposure (e.g., 1 year as a child) (Table D.1).

For carcinogenic risk, a combined child and adult receptor was used and was assumed to be exposed for a period of 33 years (21 years as a child and 12 years as an adult). Time-weighted averages for body weight and water intake were used to evaluate the combined child and adult receptor. The dose for the cancer assessment is averaged over a lifetime of exposure (e.g., 33 yr/78 yr) (Table D.2).

<u>Noncancer Health Effects</u>

The calculated exposure doses are compared to an appropriate health-based guideline for that chemical to determine whether a noncancer health hazard exists (Table D.1). Noncancer health-based guidelines are considered safe doses; that is, harmful health effects are unlikely below this level. The health guideline is based on valid toxicological studies for a chemical, with appropriate uncertainty factors built in to account for human variation, animal-to-human differences, and/or the use of the lowest study doses that resulted in harmful health effects (rather than the highest dose that did not result in harmful health effects). Being above the health-based guideline, however, does not indicate that a health hazard is present, but instead indicates that the contaminant should be further evaluated.

For noncancer effects, health-based guidelines are available from ATSDR and EPA. ATSDR health-based guidelines are called Minimal Risk Levels (MRLs) and are available at http://www.atsdr.cdc.gov/mrls.html. Reference doses (RfDs) are available from US EPA and can be found at http://www.epa.gov/iris. For this EI, health-based guidelines for noncancer effects are available for arsenic (ATSDR MRL), and manganese and uranium (EPA RfD).

To assess noncancer effects, the noncancer dose is divided by the appropriate health-based guideline (MRL or RfD) to calculate a Hazard Quotient (HQ). If the HQ is below 1, health effects are not expected to occur. If the HQ greater than 1, the COC will be further evaluated using toxicity information for the chemical provided in the scientific literature.

Table D.1. Assessment of Noncancer Hazards – Posey County EI

		Child receptor (birth to <1 yr)[1]		
COC	**Maximum Detected Concentration (μg/L)**	**Dose (mg/kg-day)**	**Toxicity Factor (mg/kg-day)**	**Hazard Quotient (dose/toxicity factor (MRL/RfD)) (unitless)**
Arsenic[2]	8	0.0011	0.0003	4
Manganese[3]	803	0.11	0.05	2
Uranium	10	0.0014	0.003	0.5

[1] An infant aged birth to <1 year reflects the most highly exposed receptor and was evaluated for noncancer effects using a body weight of 7.8 kg and ingestion rate of 1.113 L/day. The dose reflects an exposure duration of 1 year. Intake factors used to derive the doses are from USEPA, 2011.

[2]The dose for arsenic (0.0011 mg/kg/day) is for an infant. The dose associated with children aged 1 year to 21 year ranged from 0.0003 to 0.0006 mg/kg/day (HQ of 0.9 to 2). For adults, the dose associated with an HQ of 1 is 0.0003 mg/kg/day. Intake factors used to derive the doses are from USEPA, 2011.

[3]The dose for manganese (0.11 mg/kg/day) is for an infant. The dose associated with children aged 1 year to 21 year ranged from 0.03 to 0.06 (HQ of 0.5 to 1). For adults, the dose associated with an HQ of 0.6 was 0.03 mg/kg/day.

Cancer Assessment

To evaluate cancer risk associated with exposure, the exposure dose is compared to a cancer slope factor (CSF), a health-based guideline provided by USEPA (can be found at http://www.epa.gov/iris) (Table D.2). A CSF is available for arsenic.

To evaluate potential cancer effects, the doses calculated for the child/adult combined receptor (21 years as a child and 12 years as an adult for a total exposure duration of 33 years) are averaged over a 78-year lifetime and are multiplied by the CSF to calculate an excess cancer risk value. The cancer risk derived from a calculated dose reflects an increased, exposure-associated cancer risk in addition to a person's baseline risk (dose x CSF = cancer risk). Everyone has a baseline risk of developing cancer within his or her lifetime [approximately 1 in 2 for men and 1 in 3 for women (American Cancer Society, 2013)]. The risk might vary with lifestyle (e.g., smoking) or heredity. Therefore, if a cancer risk of 1 in 1,000,000 (one-in-one-million) is derived for a dose of a COC, it means that in addition to baseline cancer risk, an additional person out of a million exposed might develop cancer during his or her lifetime.

The actual increased risk of cancer is probably lower than the calculated number, which gives a theoretical worst-case excess cancer risk. The actual cancer risk can be lower, perhaps by several orders of magnitude (USEPA 1989).

Because of uncertainties involved in estimating carcinogenic risk, ATSDR employs a weight-of-evidence approach in evaluating all relevant data (ATSDR, 1993). Therefore, the carcinogenic risk is described in words (qualitatively) along with a numerical risk estimate. The numerical risk estimate must be considered in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions.

Table D.2. Assessment of Cancer Risk – Posey County EI

		Child/Adult receptor (birth to 33 yr)[1]		
COC	**Maximum Detected Concentration (µg/L)**	**Dose (mg/kg-day)**	**Cancer Slope Factor (CSF) $(mg/kg\text{-}day)^{-1}$**	**Cancer Risk (dose * CSF) (unitless)**
Arsenic	8	0.00015	1.5	2×10^{-4} (2 in 10,000)
Manganese	803	NA	NA	NA
Uranium	10	NA	NA	NA

[1] The combined child/adult receptor was evaluated for cancer. The combined child/adult aged birth to 33 yr was assessed using a time-weighted average body weight of 56 kg and ingestion rate of 2.186 L/day and was averaged over a lifetime (33 yr/78 yr).
NA = Not Applicable because manganese and uranium are not considered to be carcinogens.