Public Health Response Plan

Evaluation of

Potential Exposures from Vapor Intrusion

U.S. Marine Corps Base Camp Lejeune Camp Lejeune, Onslow County, North Carolina

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Prepared by

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ATSDR

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Scope of this Public Health Assessment

In August 1997, the Agency for Toxic Substances and Disease Registry (ATSDR) released a public health assessment (PHA) of Camp Lejeune Military Reservation in North Carolina [ATSDR 1997]. The 1997 PHA identified a public health hazard from past exposures to volatile organic compounds (VOCs) in the three drinking water systems on base. ATSDR has since undertaken additional activities to estimate historic drinking water contaminant concentrations and study the association of health outcomes to drinking water exposures on the base. ATSDR reports on Camp Lejeune and reference material are available at http://www.atsdr.cdc.gov/sites/lejeune/index.html.

Breathing indoor air contaminants in Camp Lejeune buildings affected by vapor intrusion is a distinct source of exposure to groundwater contaminants. Volatile chemicals in contaminated groundwater can seep through subsurface soils into indoor air of overlying buildings—a process termed vapor intrusion (VI).[*] The volatile chemicals of concern for vapor intrusion at Camp Lejeune are the same contaminants that were present in drinking water. These include chlorinated solvents, such as trichloroethylene (TCE), tetrachloroethylene (PCE), vinyl chloride, and related compounds and hydrocarbon compounds, such as benzene, toluene, ethylbenzene, xylenes, and others. It should be noted that vapor intrusion is only one source of these contaminants in indoor air. These contaminants are present in many industrial and household chemical compounds and are consequently also released directly into indoor or outdoor air from those sources.

At the time of the 1997 PHA, neither ATSDR nor the U.S. Environmental Protection Agency (EPA) had developed guidance for evaluating indoor inhalation exposures from vapor intrusion and did not regularly conduct such evaluations. The planned Vapor Intrusion Pathway PHA (VI PHA) will evaluate the public health implications of potential current and historical exposures to indoor air contaminants for Camp Lejeune buildings affected by vapor intrusion from underlying areas of groundwater contamination. The PHA will also evaluate the effectiveness of soil vapor mitigation systems installed in 13 buildings on base in reducing indoor air contaminant concentrations to protect health.

Background

Site Description

U.S. Marine Corps Base Camp Lejeune (Camp Lejeune) is located in the coastal plain of North Carolina, in Onslow County. The base is southeast of Jacksonville and about 70 miles northeast of Wilmington, North Carolina. The base covers a large area, approximately 151,000 acres (about 233 square miles), with 14 miles of beach on the Atlantic Ocean. Operations began at Camp Lejeune during late 1941 [Watson 1995]. The base is densely populated. At any one time, it has housed as many as 43,000 active duty military personnel and 50,000 dependents.

[*] Vapors are also released to outdoor air. However, vapors disperse more quickly in outdoor air than from soil. Therefore, high concentrations are uncommon outdoors.

History of Groundwater Contamination

Over the years, unlined landfills, leaking storage tanks, and other activities related to the use and disposal of hazardous materials have contaminated soil and groundwater at several areas on base. Discovery of contaminated water supplies at Camp Lejeune initiated a series of assessments of groundwater contamination:

- In 1983, Camp Lejeune conducted an initial assessment of potentially contaminated areas. Seventy-six potentially contaminated waste disposal sites were identified through records reviews and personnel interviews. Camp Lejeune listed 22 of those sites for further investigation.
- Camp Lejeune was listed on EPA's National Priorities List on October 4, 1989. As a result, the *Installation Restoration Program* conducted a series of assessments of groundwater contamination under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) authority.
- Additional assessments of groundwater contamination by refined petroleum products from leaking above-ground and underground storage tanks were conducted under Resources Conservation and Recovery Act (RCRA) authority.
- In 1997, ATSDR released a PHA evaluating health risks from exposures to harmful substances in the environment at Camp Lejeune, including exposures from consuming groundwater.
- Several reports summarize the findings from the Installation Restoration Program and RCRA sites [Faye et al. 2007, 2010, 2012].

Vapor Intrusion Studies and Data

In 2007, Camp Lejeune began a base-wide vapor intrusion screening evaluation to address subsurface-to-indoor air vapor intrusion exposures. CH2MHill has been conducting this evaluation under contract. Their 2009 and 2011 reports summarize the findings of their investigations to date [CH2MHill 2009, 2011].

CH2MHill's work has focused on identifying the potential for vapor intrusion within buildings located within 100 feet of known groundwater VOC contamination [CH2MHill 2008]. CH2MHill is using a phased approach consistent with guidelines in the Department of Defense Vapor Intrusion Handbook [DoD 2009] and Interstate Technology & Regulatory Council and EPA vapor intrusion guidance documents [ITRC 2007; USEPA 2002].

CH2MHill has focused their evaluation on six primary areas: Mainside, Hadnot Point, Marine Corps Air Station/New River, Courthouse Bay, Camp Geiger, and Tarawa Terrace. Multiple VOC subsurface releases have occurred in each of these areas, some of which are being actively remediated. The investigation and cleanup of these releases are being managed under several different programs, including the Installation Restoration Program, Resource Conservation and Recovery Act (RCRA), and Underground Storage Tank program.

CH2MHill used the following process to identify buildings of concern and collect sampling data [CH2MHill 2008]:

1. Non–site-specific groundwater screening levels were used to identify an initial list of 169 potential buildings of concern (open and non-occupied structures were not included in the building screening process).
2. The list was narrowed to 50 buildings of concern by developing site-specific screening levels based on building surveys and use of the Johnson and Ettinger vapor intrusion screening model.
3. Initial indoor air or soil gas samples were collected from 41 buildings with additional sampling locations added as new information became available [CH2MHill 2009, 2011, 2015].

The CH2MHill vapor intrusion studies produced a great deal of indoor air, soil gas, and shallow groundwater monitoring data. As a result, vapor intrusion management systems were installed and are operating in 12 additional buildings. The Department of Navy has also commissioned ongoing performance monitoring to make sure those systems are effective [CH2MHill 2012/13]. ATSDR has received the reports and data produced from these studies.

Industrial hygiene personnel from Camp Lejeune Naval Hospital have also conducted several building-specific indoor air monitoring surveys. These surveys were conducted in only a few buildings (Hadnot Point Industrial Area 1100, 1101, 1108, and 1115), beginning around 1999. The surveys were conducted using portable detectors, with relatively high detection limits. The results are generally non-quantitative (no explicit quality control procedures or laboratory confirmations were conducted). ATSDR has the results of those surveys and is reviewing other documents for additional air sampling data.

For a PHA, the available studies and indoor air sampling data have several limitations, including the following:

- CH2MHill began collecting air samples in 2008. By this time, extensive groundwater remediation had occurred. Consequently, vapor intrusion and indoor air contaminant concentrations may be lower than levels before groundwater remediation [Faye, et al. 2012]. Therefore, indoor air measurements from the CH2MHill studies may not represent historical long-term concentrations.
- CH2MHill included several sample locations and periods for most of the buildings sampled. Even so, the samples might be insufficient to determine if the results are representative averages of all seasons or locations within each building.
- Base industrial hygiene personnel obtained samples from many locations and periods for a few buildings. However, relatively few buildings were sampled, the results are not quantitative, and most of the contaminant-specific results were non-detections.[†]

[†] Technical guidance from the Occupational Safety and Health Administration (OSHA) indicates that qualitative photoionization detectors are appropriate for conducting area surveys and indoor air assessments of hydrocarbons and other ionizable substances (https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_3.html).

ATSDR Vapor Intrusion Evaluation Procedure

Harmful chemicals from underlying areas of groundwater contamination may have seeped into Camp Lejeune buildings. Vapors from those chemicals might be harmful if inhaled. The main objective of ATSDR's planned VI PHA is to evaluate the public health implications of potential exposures to current and historical indoor air contaminants. The PHA will use indoor air data collected by CH2MHill, additional historic vapor intrusion data, and other groundwater, soil gas, and indoor air data relevant to the evaluation. Development of the PHA will follow standard procedures outlined in the ATSDR Public Health Assessment Guidance Manual [ATSDR 2005] and technical supplement, "Evaluating Vapor Intrusion Pathways at Hazardous Waste Sites" [ATSDR 2008].

ATSDR's Planned Approach

ATSDR's work to develop the vapor intrusion PHA, further described below, includes four primary tasks:

1. Search and extract information from site documents for historical data relevant to vapor intrusion and indoor air contaminants.
2. Determine the specific contaminants and buildings that will be evaluated for vapor intrusion from building survey information and measured indoor air, soil gas, and groundwater sampling data .
3. Estimate historic indoor air contaminant concentrations from groundwater contaminant data and vapor intrusion models.
4. Evaluate public health implications of exposures to measured and estimated concentrations of indoor air contaminants from vapor intrusion.

1. Search and extract information from site documents for historical data relevant to vapor intrusion and indoor air contaminants

As a first step in the PHA process, ATSDR will search base documents for historical measurements of indoor air or soil gas to supplement the recent building-specific data obtained by CH2MHill.

Specific tasks

- Search pre-2008 site documents for historical air and soil gas measurements in or around buildings potentially affected by vapor intrusion.
- Extract relevant data from site documents and compile a database to supplement the post-2008 air and soil gas data.

2. Determine the specific contaminants and buildings that will be evaluated for vapor intrusion from building survey information and measured indoor air, soil gas, and groundwater sampling data .

ATSDR will also use available groundwater, soil gas, and air monitoring data and building survey information to identify the contaminants and buildings of concern for vapor intrusion. Building survey and inventory information will be used to determine whether potential buildings of concern have (or had) significant internal contaminant sources. Buildings such as former Bldg. 25 (site 88) which had a PCE dry cleaning facility, and Bldg. 902 (site 78) which included usage of TCE degreasing solvents for vehicle maintenance, will be excluded from VI evaluation (for those specific contaminants) because the internal contaminant sources overwhelm the potential VI source. These exclusions will be determined on a contaminant and building -specific basis.

Specific Tasks

- Use the building screening list developed by CH2MHill to identify buildings of concern (see Table 1 for the buildings that will be evaluated). Those will include
    - Buildings within 100 feet of groundwater with contaminant concentration above groundwater screening values [CH2MHill 2008]. Note that the groundwater screening values used by CH2MHill are based on concentrations likely to produce indoor air contaminant concentrations above the USEPA Regional Screening Levels for industrial exposures [US EPA 2008].
    - Buildings with a preferential pathway for vapor intrusion [such as underground utility lines that lead to a building from a subsurface contaminant source; CH2MHill 2008] and,
    - Buildings.
    - Evaluate the potential for vapor intrusion in buildings with sensitive populations, such as schools and daycare centers by determining whether those building overlie or are within 100 feet of areas of groundwater contaminated by volatile compounds. Buildings within 100 feet of contaminated groundwater or for which inadequate groundwater data are available will be retained for additional characterization as below.
- Calculate building-specific groundwater-to-indoor air attenuation factors from measured 2008-2010 groundwater and indoor air contaminant concentrations. Note that the building-specific attenuation factors will account for all of the building construction variables and contaminant-specific degradation factors relevant to the vapor intrusion process.
    - Calculate building average indoor air contaminant concentrations from available measured data. Short term (hours to 14 days) averages will be based on combining synchronous within-building samples. Long term averages (months to years) will be based on combining all samples for each building. The building-specific temporal and spatial representativeness of the average values will be evaluated as permitted by the available data. .
    - Building-specific average groundwater contaminant concentrations will be calculated from shallow (water table wells; 8-12 ft. below ground surface)

groundwater samples adjacent to each building. Most potentially affected buildings appear to have 3 to 5 nearby shallow wells.

- Note that the building-specific groundwater to indoor air attenuation factor is a simple empirical ratio ([measured IA concentration]/[measured GW concentration]).

3. Estimate historic indoor air contaminant concentrations from groundwater contaminant data and vapor intrusion models.

ATSDR will use the calculated groundwater to indoor air attenuation factors to estimate building-specific indoor air concentrations for pre-2008 periods when only groundwater contaminant concentrations are available.

Specific Tasks

- Derive pre-2008, building-specific shallow groundwater contaminant concentrations from groundwater monitoring data, supplemented with ATSDR groundwater modeling results.
- Estimate building-specific indoor air contaminant concentrations using the empirical groundwater to indoor air attenuation factors and historic groundwater data.
- Supplement the estimated building-specific indoor air concentrations with information obtained during the data search task.

4. Evaluate public health implications of exposures to measured and estimated concentrations of indoor air contaminants from vapor intrusion

After estimating the historic indoor air contaminant concentrations, ATSDR will use its health assessment procedures to evaluate the public health implications of potential exposures to building occupants [ATSDR 2005, 2008]. ATSDR will focus this evaluation on the five contaminants detected in indoor air of 17 buildings at concentrations above health comparison values: benzene, chloroform, 1,2-dichloroethane, PCE, and TCE. In this task, uncertainty of the building-specific indoor air contaminant concentrations will be assessed by re-calculating the attenuation factors using probability distributions of the respective groundwater and indoor contaminant concentrations.

Specific Tasks

- Use a probabilistic model (Monte Carlo or equivalent) to evaluate the indoor air and groundwater concentrations underlying the empirical attenuation factors. Perform parameter sensitivity analyses to document the relative uncertainty of model parameters.
- Evaluate chronic health effects and cancer risks using the average value of a calculated distribution of indoor air measurements for each building.

- Evaluate short-term health effects using synchronous, within-building average indoor air measurements for the sample event that had the highest measured concentrations.
- Determine potential exposures in buildings with measured or estimated indoor air contaminant concentrations above the health screening values. Compare those values with the contaminant-specific health effects summarized in the respective toxicological literature.
    - Define building-specific exposures according to building use and occupant surveys (as conducted by CH2MHill or in building inventories). Note that historic building use information may be limited.
    - Adjust residential non-cancer health screening values (based on continuous exposure) to occupational exposure durations (8 hours per day, 5 days per week), where appropriate (Table 2).
    - Adjust ATSDR cancer risk evaluation guides, based on 78 year exposures, for occupational exposures of 15 years (Table 2).
- Determine exposure factors, such as daily and lifetime base worker and military personnel exposure durations, from the EPA Exposure Factors Handbook [EPA 2011], ATSDR Addendum on Camp Lejeune Drinking Water Exposures, or the Department of Defense Vapor Intrusion Handbook [DOD 2009].
- Use available air monitoring data to determine whether the existing vapor intrusion management systems protect human health.

Table 1. Camp Lejeune buildings of concern for vapor intrusion (based on CH2MHill screening criteria) [CH2MHill 2008, 2009, 2011].

Building No.	VIMS installed	Building type/construction	Use/occupants
Mainside			
3	Mar-12	2-story brick, slab foundation above grade (1 ft)	office space; ~50 workday occupants
3B	Mar-12	1-story concrete block, slab on grade	office space; ~5 workday/weekend occupants
37	Mar-12	1-story concrete block, slab on grade	office space/classrooms; ~25 workday occupants
43	Mar-12	1-story concrete block, slab on grade	office space; 10 workday occupants
4		1-story brick, slab on grade	office space, classroom; ~5 workday occupants w/20 occasional students
HP-57		3-story brick; slab on grade	barracks; 90 dorm rooms
1827		1-story polycarbonate, slab on grade	storage, not regularly occupied
1828		1-story corrugated steel; slab on grade	primarily storage, 1 office and classroom; <10 workday occupants
1855		1-story brick,	primarily storage, with offices (window A/C)
820	SVE circa 1997	1-story concrete block, slab on grade	gas station/convience store; 10 workday occupants
LCH-4015		large brick/mortar building; slab on grade	community/fitness ctr, movie theater, post office, etc.; < 100 occupants, various hours
Hadnot Point			
901		1-story corrugated steel/fiberglass; slab on grade	vehicle maintanance, offices and classroom; ~5 workers with 20 part-time students
902	Mar-12	1-story brick; slab on grade; 400x200ftx15/20ft high	mostly storage w/offices; ~5 workday occupants
903		1-story brick; slab on grade; 400x200ftx15/20ft high	mostly storage w/offices; ~5 workday occupants
1502		1-story concrete blk; slab on grade; large bay doors	vehicle maintanance w/ offices; ~33 workday occupants
1601		1-story concrete blk; slab on grade; large bay doors	mostly storage w/offices; ~50 workday occupants
1603		1-story concrete blk; slab on grade; central HVAC	offices, large work area, classroom; 15 workday occupants
1606			
1707			
1817			
1819			
1611			
1613			
1005	Mar-12	1-story concrete block, slab on grade	offices; multi-zone HVAC; ~100 workday occupants
1068			
1114			
1220			
1100		1-story concrete block, slab on grade	offices, 2 workday occupants
1101	1999 thru 2000	mostly 1-story concrete block (SW section 2-stories); 4' abo	storage /warehouse w/offices in 2-story section; ~50 workday occupants
1111			
1115	Mar-12	1-story concrete block, slab on grade	storage, small engine repair; ~2 workday occupants
1108	Feb-07	mostly 1-story concrete block (SW section 2-stories); 4' abo	rehouse w/offices in 2-story section; ~50 workday occupants, hundreds short time durir
1200	Feb-07		
1201	Feb-07	1-story concrete block, slab above grade (~3.5')	warehouse w/small office NE corner; ~5 workday occupants
1202	Feb-07		
1301	Feb-07	1-story concrete block, slab above grade (~5')	warehouse w/small office NE/NW corners; ~20 workday occupants
MCAS, New River; Courthouse Bay; Camp Geiger			
AS502		1-story concrete block, slab on grade,	fire station/crash response, offices; ~15 workday occupants, 3 on call workers
AS541			
AS4106			
A47		1-story concrete block, 400'x200'x25'high; slab on grade	vehicle maint. w/shops, offices; 50-100 workday occupants
G480		1-story concrete block	storage, classrooms, offices
G531		3-story brick, ~100ft x 50 ft, 10ft ceilings	~1/3 of each flr office/restroom/laundry, remainder open barracks
G532		3-story brick, ~100ft x 50 ft, 10ft ceilings	~1/3 of each flr office/restroom/laundry, remainder open barracks
G533		3-story brick, ~100ft x 50 ft, 10ft ceilings	~1/3 of each flr office/restroom/laundry, remainder open barracks
TC860			
TC864			
Phase III-No Further Action			
VIMS installed/recommended			

Table 2. ATSDR inhalation comparison values with adjustments from continuous residential exposure duration to shorter term occupational durations

	ppbv	ppbv	ppbv	indoor air ppbv	
	EMEG	EMEG- adj	CREG	Occup. CV	1E-04 CREG-adj
1,2-dichloroethane	600	2520	0.0095	0.2	21.6
1,4-dichlorobenzene	10	42		42	
benzene	3	12.6	0.04	0.9	91.1
chloroform	20	84	0.0089	0.2	20.3
ethylbenzene	60	252		252	
tetrachlorethylene	40	168	0.57	13.0	1298.2
toluene	80	336		336	
trichloroethylene	0.37	1.554	0.045	1.0	102.5
vinyl chloride			0.044	1.0	100.2
xylenes, total	50	210		210	

Abbreviations: ppbv = parts per billion by volume; EMEG = environmental media evaluation guide; EMEG-adj = EMEG adjusted for occupational duration exposures (8 hours/day; 5 days/week); CREG = cancer risk evaluation guide (based on continuous exposure for 78 years); Occup. CV = occupational coefficient of variation: lower of EMEG-adj or CREG-adj (with 1E-06 excess cancer risk and 15 year exposure); 1E-04 CREG-adj = CREG adjusted for occupational duration exposures and 1E-04 excess cancer risk for 15 years. 5.

Presentation and Documentation of Results

ATSDR will publish the results of the Camp Lejeune vapor intrusion evaluation in a PHA. Steps in preparing the PHA will include the following:

- Identification and documentation of limitations in the available data and evaluation procedure.
    - Most buildings have had multiple indoor air measurements at several times and sample locations, though too few for quantitative uncertainty analyses.
    - Many of the affected buildings are multi-purpose. They have a combination of office and storage spaces, variable ceiling heights, and heating/cooling systems, leading to highly variable potentials for vapor intrusion. Intra-building soil gas and indoor air measurements reflect this variability.
    - Vapor intrusion can vary at different times. The water table might rise during certain seasons, forcing vapors through the soil. Groundwater remediation might also affect long-term trends.

  - A few buildings have been subject to dozens of qualitative air measurements over multiple years. Measurements using photoionization detector (PID) and flame ionization detector (FID) vapor detection meters cover three orders of magnitude. These measurements provide an estimate of variability in those buildings by time and location.
  - Ongoing measurements of vapor intrusion management systems are conducted quarterly. A few buildings have been subject to multiple measurements over multiple seasons. These measurements will be evaluated to assess seasonal variability.
  - Most of the environmental sampling data for this evaluation have undergone appropriate laboratory quality control. The Department of Navy or other regulatory agencies have accepted these date for use.
  - The only data used that have not undergone quality control evaluation are the building-specific PID measurements collected by the base industrial hygiene group. These data are only used to assess variations by time and location within specific buildings. Therefore, only the overall variability of each dataset is considered; the individual values are irrelevant.
  - The groundwater model results used to supplement measured groundwater concentrations have undergone quantitative uncertainty analysis and will be appropriately referenced.

- The ATSDR VI evaluation process [ATSDR 2008] recommends the use of multiple lines of evidence to address the uncertainties inherent in public health assessment of VI exposures. As such, this PHA will rely on consistency across the indoor air, soil gas, and groundwater data sources on a building by building basis in order to develop defensible public health conclusions.

- Peer review through procedures established by the ATSDR Office of Science.
- Review and comment by the public and external stakeholders.
- Inclusion in the final version of the VI PHA of comments and responses indicating how each comment was addressed.

Proposed Timeline

To date, ATSDR has identified and organized approximately 24,000 historical documents 4/20/2015April 20, 2015and reports containing data of interest for the VI PHA. Work on the PHA will continue to progress in line with the timeline in Table 3.

Table 3. Timeline for ATSDR's Vapor Intrusion Public Health Assessment

Activity	Start	Finish
Organize and categorize relevant documents from Department of Navy, U.S. Environmental Protection Agency, and North Carolina Department of Environment and Natural Resources	1/02/2013	Completed
Identify indoor air and soil gas data for buildings of interest, extract data, and enter the data into a database	03/01/2015	11/15/2015
Summarize and analyze data for spatial and temporal trends and use the results to inform ATSDR's assessment of exposures	11/15/2015	3/30/016
Prepare PHA and release for peer review	3/30/2016	9/15/2016
Update the PHA based on peer review comments and release PHA for public comment	9/16/2016	6/16/2017
Update the PHA based on public comments and release final PHA	6/17/2017	12/31/2017

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