# Exhibit 184

# Morbidity Study of Former Marines, Employees, and Dependents Potentially Exposed to Contaminated Drinking Water at U.S. Marine Corps Base Camp Lejeune

April, 2018

# Morbidity Study of Former Marines, Employees, and Dependents Potentially Exposed to Contaminated Drinking Water at U.S. Marine Corps Base Camp Lejeune

**CONTENTS**

## EXECUTIVE SUMMARY

### Introduction

On January 28, 2008, President George W. Bush signed H.R. 4986, the National Defense Authorization Act for Fiscal Year 2008 which required the Agency for Toxic Substances and Disease Registry (ATSDR) to develop a health survey that would collect personal health information from all persons who could be identified as potentially exposed to drinking water contaminated with trichloroethylene (TCE), tetrachloroethylene (PCE), and other volatile organic compounds at Camp Lejeune. In response to this Act, ATSDR conducted a health survey in 2011-2012 to collect information on cancers, other diseases of interest, and lifestyle and demographic factors. The survey specifically asked about cancers and diseases that were selected based on an extensive literature review of occupational and drinking water studies involving solvent exposure. The survey included cancers of the bladder, brain, breast, cervix, colon, esophagus, hematopoietic system (lymphoma, leukemia, and multiple myeloma), kidney, liver, lung, larynx, pancreas, pharynx, prostate, rectum, and soft tissue; amyotrophic lateral sclerosis (ALS); aplastic anemia; endometriosis; infertility; kidney and liver diseases; lupus; multiple sclerosis (MS); Parkinson disease; scleroderma; and trichloroethylene-related skin disorders.

### Methods

The survey sought to include

- 214,970 Marines and Navy personnel ("Marines") who were stationed at Camp Lejeune anytime during April 1975 – December 1985
- 50,000 Marines randomly sampled from those stationed at Camp Pendleton for any duration from April 1975 – December 1985 but not stationed at Camp Lejeune during this timeframe

- 8,085 civilians employed at Camp Lejeune anytime during October 1972 – December 1985
- 7,236 civilians employed at Camp Pendleton anytime during October 1972 – December 1985 but not employed at Camp Lejeune during this period

ATSDR also sent surveys to 29,996 Marines, their spouses, and their children (who were born before 1986 and are now adults) who were included in the 1999-2002 ATSDR survey of children born at Camp Lejeune. Marines from the 1999-2002 ATSDR survey who were stationed at Camp Lejeune after March 1975 were included in the Marine cohort.

Surveys were sent to those for whom we could find accurate and complete addresses (n=247,479): 179,158 Marines who were stationed at Camp Lejeune; 5,440 civilians employed at Camp Lejeune; 16,736 Marines, spouses, and their children in the 1999-2002 ATSDR survey; 41,761 Marines who were stationed at Camp Pendleton; and 4,384 civilians employed at Camp Pendleton. The health survey was used to obtain information on specific health outcomes, residential history, and potential confounders.

The data from the health survey were used to conduct a morbidity study to evaluate whether exposure to the contaminated drinking water at Camp Lejeune was associated with medically confirmed specific diseases of interest listed above. This report describes the results of the morbidity study. Marines and civilian employees were analyzed separately because their exposure scenarios differed. The primary exposure to drinking water contaminants for the Camp Lejeune civilian workers was at the workplace, whereas Camp Lejeune Marines could be exposed at their residences and during training and other activities on base. To examine exposure, ground water contamination fate and transport models and water distribution system models were used to estimate monthly contaminant

levels of TCE, PCE, and other volatile organic compounds at Camp Lejeune residences and workplaces.

For analyses of Marines, we first compared the Camp Lejeune cohort to the Camp Pendleton cohort using all morbidity study participants. These analyses assumed that all Marines stationed at Camp Lejeune were exposed to the contaminated drinking water (if not at their residence then during field training and other activities at the base). Next, we evaluated contaminant-specific residential exposures (e.g., cumulative and average residential exposure to each contaminant) using a nested case-control sample of Marines at both bases. For the nested case-control sample, residential locations and periods of residence at Camp Lejeune were assigned using information from survey responses, unit codes and periods of service from the Defense Manpower Data Center (DMDC) personnel data, and Camp Lejeune housing records. The nested case-control sample included all medically confirmed cases of the diseases of interest among Marines and a random sample of 3,000 Marines who did not report a disease of interest. For the nested case-control sample, one set of analyses used the Camp Pendleton Marines as the referent, and a second set of analyses ("internal analyses") was restricted to Camp Lejeune Marines with no/low residential exposure as the referent.

For civilian employees, all analyses included all Camp Lejeune and Camp Pendleton workers in the study. We used historical occupation codes, period, and duration of employment from the DMDC personnel database, and information from base staff on workplace locations to assign cumulative and average exposures to each of the contaminants. First, we compared civilian employees at Camp Lejeune with those at Camp Pendleton. Next, we conducted categorical analyses of civilian employees with Camp

Pendleton workers as the referent as well as internal analyses that were restricted to Camp Lejeune civilian workers with no/low cumulative exposure as the referent. Results of categorical analyses for civilian employees are presented for TCE only because the correlation between TCE and PCE exposures among the Camp Lejeune civilian workers was approximately 1.0.

For male Marines and civilian employees, cut points at the 50$^{th}$ ("medium exposure") and 90$^{th}$ ("high exposure") percentiles of estimated TCE and PCE exposure levels were used to categorize the exposures. For female Marines, cut points at the 75$^{th}$ and 90$^{th}$ percentiles were used to categorize exposures because the 50$^{th}$ percentile was 0 parts per billion (ppb) for the contaminants.

We used unconditional logistic regression to compute odds ratios (ORs) and their 95% confidence intervals (CIs). Models for individual cancers were adjusted for age at diagnosis if there were >2 cases per cell. Additionally, models were adjusted for confounders when the unadjusted and adjusted results differed by >10%.

We did not use statistical significance to interpret the results. We did not want to make a qualitative decision about the importance of a result in this study based on an arbitrary cutoff for "significance" (e.g., $p < 0.05$ or a 95% CI that does not include the null value) (Rothman et al. 2008). This is because a result that fails to achieve statistical significance can still provide potentially useful information, and a result that achieves statistical significance can lack scientific and public health significance (Porta 2014).

We instead interpreted study results based on the magnitude of the OR and consistency with results from other published studies. Although all ORs are provided in the tables, ORs ≥1.5 for cumulative exposures to TCE or PCE in the internal analyses for

both Marines and civilian employees are highlighted in the Discussion section and summary table of key results (Table 21) according to the following hierarchy:

- The ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases (ATSDR 2017) concluded that the evidence for causation for the disease and contaminant was at least "equipoise and above."
- If the 2017 ATSDR assessment concluded that the evidence was below equipoise, we did not highlight the disease-contaminant pair.
- If the 2017 ATSDR assessment did not evaluate the disease, then we checked if the result was supported by the previous mortality studies at Camp Lejeune (Bove et al. 2014a, b).

The decision to highlight ORs $\geq$1.5, although arbitrary, is supported by empirical studies indicating that confounding bias, if present, would change an effect estimate such as the OR by no more than 0.2 or 0.3 (Kriebel et al. 2004, Blair et al. 2007). Based on considerations of the impact of variability and confounding, one epidemiological text book considered ratio estimates of $\geq$1.5 as indicating a "moderate" strength of association (Monson 1990). Some ORs for specific diseases in the tables are <1.0 (e.g., for male infertility and lupus in the internal analyses of Camp Lejeune Marines). These ORs are interpreted as providing no support for our hypotheses that the exposures to contaminated drinking water at Camp Lejeune increased the risk for these diseases. We are not aware of any mechanism by which exposure to the chemicals in the drinking water at Camp Lejeune could be considered protective for the specific adverse health outcomes

evaluated in this study. ORs <1.0 may be due to biases including selection and exposure misclassification as well as random error due to small numbers for discrete endpoints.

We also indicate on Table 21 if there was a monotonic exposure-response relationship. Monotonic exposure response relationships occur when every change in the OR with increasing category of exposure is in the same direction, although the trend could have flat segments but never reverse direction (Rothman et al. 2008). However, we acknowledge that exposure misclassification could distort exposure-response relationships, e.g., producing non-monotonic trends that attenuate or turn negative at higher exposure levels (Stayner et al. 2003).We provided the confidence interval to indicate the level of uncertainty or precision of the point estimate.

**Results and Conclusion**

Of the 247,479 surveys that were mailed to cohort members with accurate addresses, 76,058 surveys were completed for a response rate of 31%. Participants who reported a disease of interest were sent a Health Insurance Portability and Accountability Act (HIPAA) form allowing us to seek medical confirmation. Completed HIPAA forms were available for 56% of Camp Lejeune Marines (n=10,655), 51% of Camp Pendleton Marines (n=2,335), 66% of civilian employees from Camp Lejeune (n=786), 60% of civilian employees from Camp Pendleton (473), and 61% of persons in the previous ATSDR survey (n=1,585).

For cumulative exposures to TCE and PCE in internal analyses, the morbidity study found that contaminated drinking water at Camp Lejeune was associated with increased risk in both Marines and civilian employees for bladder cancer, kidney cancer, and kidney disease and that these results were informed by evidence from other studies. For bladder cancer, ORs were ≥1.5 for PCE in Marines and for TCE/PCE in civilian

employees, and results for PCE were supported by the ATSDR assessment (ATSDR 2017). For kidney cancer, ORs were ≥1.5 for both TCE and PCE in Marines and for TCE/PCE in civilian employees; results for TCE were supported by the ATSDR assessment (ATSDR 2017) and for both TCE and PCE in the previous Marine mortality study at Camp Lejeune (Bove et al. 2014a); and monotonic exposure-response relationships were observed for both TCE and PCE in Marines and for TCE/PCE in civilian employees. For kidney disease, ORs were ≥1.5 for PCE in Marines and for TCE/PCE in civilian employees; both TCE and PCE results were supported by the ATSDR assessment (ATSDR 2017); and monotonic exposure-response relationships were observed for PCE in Marines and for TCE/PCE in civilian employees.

Although ORs for Parkinson disease and TCE and PCE in Marines were <1.5, ORs were ≥1.5 for TCE/PCE in civilian employees; TCE results were supported by the ATSDR assessment (ATSDR 2017); and both TCE and PCE results were supported by the previous mortality study in civilian employees at Camp Lejeune (Bove et al. 2014b). Additionally, a monotonic exposure-response relationship was observed in civilian employees. Parkinson disease is mostly diagnosed in persons age ≥65 years with peak incidence among persons aged 70-79 years (Hirsch et al. 2016). About 49% of civilian employees were ≥65 years of age compared with only 7% of Marines being ≥65 years of age.

Study results add to the scientific literature and suggest possible associations between the chemicals in the drinking water at Camp Lejeune and these diseases. However, results of this study need to be interpreted with caution for several reasons. First, the low response rate and small numbers for some of the diseases of interest

resulted in wide CIs. Second, selection bias could have impacted analyses comparing Camp Lejeune to Camp Pendleton, likely biasing results away from the null (potentially overestimating the effect of the exposures) because those at Camp Lejeune with health problems may have been more likely to participate than those at Camp Pendleton with health problems. The Camp Lejeune participants with health problems may have been more likely to participate because they were aware of the contaminated drinking water and believed they were affected by their exposures.

Additionally, the study results could have been impacted by exposure misclassification bias. Exposure misclassification bias could have resulted because of errors in base assignments, limited information on each unit's barrack location, lack of information on how much drinking water was consumed at the Marine's residence, lack of data on where a Marine at Camp Lejeune trained on-base and drinking water use during training, inability to accurately capture time spent away from the base for training or deployment, uncertainty about the drinking water use of civilian workers at Camp Lejeune, and uncertainty about workplace locations (e.g., during the workday, a worker might have been assigned to multiple locations at the base). The exposure misclassification bias is likely non-differential because the errors in exposure assignments should be unrelated to diseases status. Non-differential exposure misclassification bias would likely bias comparisons between Camp Lejeune and Camp Pendleton towards the null, or in other words, possibly result in underestimating the effect of exposures at Camp Lejeune. Non-differential exposure misclassification bias could also impact the internal analyses of Camp Lejeune cohorts by distorting exposure-response relationships, e.g., producing non-monotonic trends that attenuate or turn

negative at higher exposure levels.

Given the major limitations of this study, ATSDR is conducting additional research of the Camp Lejeune cohorts to help further evaluate the incidence of cancer in this population.

## INTRODUCTION

The United States Marine Corps (USMC) Base at Camp Lejeune, North Carolina began operations during the early 1940s. During the base's 1980-85 water-quality testing and sampling program, volatile organic compounds (VOCs) were detected in some supply wells that provided drinking water for some of the barracks, family housing, and other buildings on base. The VOCs included trichloroethylene (TCE), tetrachloroethylene (PCE), vinyl chloride, and benzene. The Agency for Toxic Substances and Disease Registry (ATSDR) determined that contamination began in the 1950s and continued until the most highly contaminated wells were removed from service in February 1985 (Maslia et al 2007, 2013). Maximum measured concentrations of selected contaminants in drinking water were 215 parts per billion (ppb) of PCE in the Tarawa Terrace distribution system in February 1985 and 1,400 ppb of TCE in the Hadnot Point distribution system in May 1982. PCE was also present in the Hadnot Point system (maximum measured concentration was 100 ppb in February 1985), and vinyl chloride and trans-1,2-dichloroethylene (DCE) were present in the distribution system due to degradation of TCE. Benzene was also present in the Hadnot Point system. The sources of contamination were attributed to a privately owned dry cleaning business adjacent to Camp Lejeune for Tarawa Terrace and base activities such as leaking underground storage tanks, industrial area spills, and waste disposal sites releasing fuel and chlorinated solvents for Hadnot Point.

ATSDR conducted a historical reconstruction and modeling of the groundwater to estimate monthly levels of contaminants in water supply wells and the drinking water distribution systems from 1942 to 1987 (Maslia et al. 2007, 2013). ATSDR concluded

that individuals served by the Tarawa Terrace Water Treatment Plant (WTP) from November 1957 through February 1987 received drinking water contaminated with PCE at levels that exceeded the current U.S. Environmental Protection Agency (EPA) maximum contaminant levels (MCL) of 5 ppb and that individuals served by the Hadnot Point WTP from August 1953 through mid-February 1985 received drinking water contaminated with one or more VOCs at levels that exceeded current MCLs. A third water system, Holcomb Boulevard, was primarily uncontaminated except when intermittently supplemented with contaminated Hadnot Point drinking water during some of the dry spring and summer months of 1972-1985. Hadnot Point also supplied Holcomb Boulevard's drinking-water system when its plant was shut down during January 27-February 7, 1985.

TCE, vinyl chloride, and benzene are classified as human carcinogens based on the associations between TCE and kidney cancer, benzene and acute myeloid leukemia, and vinyl chloride and angiosarcoma of the liver, while PCE is classified as a "likely" or "probable" human carcinogen based on evidence of associations with liver cancer and mononuclear cell leukemia in animal studies (IARC 2008, 2012, 2014; EPA 2011, 2012; NTP 2016). Several meta-analyses and reviews have assessed the health effects of these VOCs (EPA 2011, 2012; IARC 2008, 2012, 2014; Karami et al. 2012, 2013; NTP 2015, 2016; Scott and Jinot 2011; Vlaanderen et al. 2014). For these VOCs, epidemiological studies are mostly limited to occupational exposures which are typically much higher than environmental exposures  Literature on health effects of drinking water exposures to these chemicals is limited.

Previous mortality studies conducted of Marines and Navy personnel and civilian

employees at Camp Lejeune by ATSDR found elevated risks for deaths from cancers of the lung, kidney, prostate, rectum, leukemia and multiple myeloma (Bove et al. 2014a, b). Additionally, risk for deaths from cancers of the esophagus, liver, pancreas, cervix, and soft tissue were elevated in Marines and Navy personnel, and risk for deaths from cancers of the female breast and oral cavity were elevated in civilian employees. Drinking water studies conducted in other populations found associations between TCE and leukemia and non-Hodgkin lymphoma (NHL); PCE and NHL; and PCE and lung cancer, bladder cancer, leukemia, rectal cancer, and female breast cancer (Aschengrau et al. 1993, 2003; Cohn et al. 1994; Paulu et al. 1999; Vieira et al. 2005). To date, no studies have evaluated associations between drinking water exposures to these chemicals and medically confirmed, non-cancer diseases in adults.

On January 28, 2008, President George W. Bush signed H.R. 4986, the National Defense Authorization Act for Fiscal Year 2008 which required ATSDR to develop a health survey that would be sent to all persons who could be identified as potentially being exposed to contaminated drinking water at Camp Lejeune. The Act further stated that the health information collected in the survey could provide a basis for scientific studies. In response to this Act, ATSDR conducted a health survey in 2011-2012 to collect information on cancers, other diseases of interest, and information about lifestyle and demographic factors. The information collected in the health survey was used to conduct a morbidity study to evaluate whether exposure to the contaminated drinking water at Camp Lejeune was associated with medically confirmed diseases of interest. The diseases of interest were selected based on an extensive literature review of occupational and drinking water studies involving solvent exposure (Bove and Ruckart

2008). The literature review identified the following diseases for inclusion based on evidence of positive associations in epidemiological studies: cancers of the bladder, brain, breast, cervix, esophagus, hematopoietic system (lymphoma, leukemia, and multiple myeloma), kidney, liver, lung, pancreas, and soft tissue, aplastic anemia, generalized skin disorders, kidney diseases, lupus, Parkinson disease, and scleroderma. Subsequent evaluation of the literature on the health effects of chlorinated and aromatic solvent exposures identified additional diseases for inclusion based on evidence of positive associations in epidemiological studies: cancers of the colon, larynx, pharynx, prostate, and rectum, amyotrophic lateral sclerosis (ALS), endometriosis, infertility, liver diseases, and multiple sclerosis (MS).

## METHODS

### Study Hypotheses

The morbidity study evaluated the following hypotheses:

1. Marines and civilian employees at Camp Lejeune had higher prevalence of specific cancers and other diseases than Marines and civilian employees at Camp Pendleton.

2. Marines at Camp Lejeune with higher residential exposures had higher prevalence of specific cancers and other diseases than Marines at Camp Pendleton.

3. Marines at Camp Lejeune with higher residential exposures had higher prevalence of specific cancers and other diseases than Marines at Camp Lejeune with lower residential exposures.

4. Civilian employees at Camp Lejeune with higher workplace exposures had higher prevalence of specific cancers and other diseases than civilian employees at Camp Pendleton.

5. Civilian employees at Camp Lejeune with higher workplace exposures had higher prevalence of specific cancers and other diseases than civilian employees at Camp Lejeune with lower workplace exposures.

**Study Population and Eligibility**

To define the study population, we used the Defense Manpower Data Center (DMDC) personnel databases and the 1999-2002 ATSDR survey on birth defects and childhood cancers to identify persons for the morbidity study who lived or worked at Camp Lejeune during the period of drinking water contamination. Marines and Navy personnel ("Marines") included in both the DMDC database and the ATSDR 1999-2002 survey were assigned to the Camp Lejeune Marines cohort.

A comparison population was randomly sampled from Marines stationed at Camp Pendleton, and a cohort of civilian workers employed at Camp Pendleton was also included. Camp Pendleton, located along the Southern California coast in northern San Diego County and southern Orange County, did not have VOC-contaminated drinking water during the period evaluated in this analysis (ATSDR 2008). Additionally, the inclusion criteria specified that the individuals in the comparison population could not have lived or worked at Camp Lejeune during the period of drinking water contamination. A comparison population was unavailable for the 1999-2002 ATSDR survey cohort.

Although the DMDC began personnel data collection for Marines in the second quarter of 1971 (semi-annually), quarterly data, including the unit codes needed to identify where Marines were stationed, are only available beginning in the second quarter of 1975. DMDC began collecting civilian worker personnel data in the last quarter of 1972, although data were not available for the first quarter of 1973. The current study initially sought to enroll 310,287 individuals:

- 214,970 Marines who were stationed at Camp Lejeune anytime during April

1975 – December 1985

- 50,000 Marines randomly sampled from those stationed at Camp Pendleton anytime during April 1975 – December 1985
- 8,085 civilians employed at Camp Lejeune anytime during October 1972 – December 1985
- 7,236 civilians employed at Camp Pendleton anytime during October 1972 – December 1985

All civilian employees from Camp Lejeune and Camp Pendleton were included in the initial study population. Additionally, surveys were sent to 29,996 Marines, their spouses, and their children (who were born before 1986 and are now adults) who were included in the 1999-2002 ATSDR survey of children born at Camp Lejeune. Marines from the 1999-2002 ATSDR survey who were stationed at Camp Lejeune after March 1975 were included in the Marine cohort.

Accurate and complete addresses were necessary for participant eligibility (n=247,479) (Table 1). Addresses were available for 179,158 Marines who were stationed at Camp Lejeune; 5,440 civilians employed at Camp Lejeune; 16,736 Marines, spouses, and their children from the 1999-2002 ATSDR survey; 41,761 Marines who were stationed at Camp Pendleton; and 4,384 civilians employed at Camp Pendleton.

**Data Collection**

This retrospective cohort morbidity study used an Office of Management and Budget (OMB) approved health survey to identify individuals who developed cancers and diseases of interest and to obtain information on residential history at each base and on demographic and lifestyle factors. This study received approval from the Centers for

Disease Control and Prevention's Institutional Review Board.

We used Dillman's Tailored Design Method to encourage survey participation (Dillman 2007). Participants were mailed a personalized pre-notice letter signed by the USMC Deputy Commandant for Installations and Logistics explaining that they would be receiving a survey. A personalized letter of invitation, hardcopy survey, preaddressed stamped return envelope, and email (if possible) were sent one to two weeks after the pre-notice letter; the letter of invitation directed participants to a web-based version of the survey if they preferred to answer on-line. After two weeks, a postcard reminder/thank you and email were sent to all participants. A second survey was sent to those participants who had not responded within four weeks after receiving the postcard reminder. Participants who did not respond to the survey within two weeks after the second mailing received interactive voice-response (IVR) telephone reminders.

To minimize information bias, the letter of invitation, e-mail invitation, and consent form did not specifically mention the contaminated drinking water. Instead, the communication materials informed respondents that ATSDR was conducting a research activity to learn more about the health effects of workplace and environmental exposures to chemicals. The survey also did not request information on drinking water usage. For study participants identified through the ATSDR Camp Lejeune mortality studies (Bove et al. 2014a, b) or address tracing services as having died, surveys were mailed to the next of kin if the name and address were available. Surveys were sent during June 2011 – December 2011.

ATSDR used various efforts to inform the community of former Marines, dependents, and civilian employees about the health survey and to encourage those who

received surveys to participate. ATSDR provided materials to media outlets and non-governmental agencies; posted materials on the ATSDR Camp Lejeune website including a video encouraging participation from Captain Dale A. Dye, USMC (Ret)., a former Marine who is a Hollywood actor; and used social media. ATSDR also coordinated with the USMC to conduct additional outreach.

Informed consent, either hardcopy or electronic, was obtained from the participants. The health survey collected information on diseases an individual may have had that were diagnosed by a health provider between the time the individual first lived, was stationed, or worked at either Camp Lejeune or Camp Pendleton and when the survey was completed. The diseases included several cancers, ALS, aplastic anemia, endometriosis, infertility, severe kidney diseases, severe liver diseases, lupus, MS, Parkinson disease, scleroderma, and TCE-related skin disorders. Requested information for cancers included the type of cancer, date of diagnosis, and state of diagnosis to facilitate the acquisition of cancer registry data. The survey also collected information on residential history on base, occupational history, reproductive history (for females), demographics, education level, and smoking and alcohol consumption. The survey included space for respondents to report other diseases/conditions not specifically mentioned in the questionnaire.

Self-reported cancers and other diseases of interest were confirmed by medical records, cancer registry information, or death certificates. Participants who reported a disease of interest were mailed a Health Insurance Portability and Accountability Act (HIPAA) form to facilitate confirmation via medical providers or cancer registries. We sent reminder HIPAA forms and conducted reminder IVR phone calls to participants who did

not respond within 5 weeks of the first HIPAA mailing. Alternately, participants could have provided a copy of their medical record to ATSDR.

ATSDR received approvals from 13 state cancer registries that had 100 or more participants who reported a cancer (California, Florida, Georgia, Indiana, Michigan, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia) to assist in confirming the self-reported cancers; these states accounted for approximately 60% of all cancers reported in the survey. We also received approval from the Department of Veterans Affairs Central Cancer Registry. Because of the low number of cancers reported in some states and the amount of time and effort involved in obtaining approvals from the state registries, we did not seek cooperation from all 50 states.

**Exposure Assessment**

As limited historical, contaminant-specific water contamination data were available, ATSDR previously conducted a historical reconstruction of the spatial and temporal distribution of the drinking water contaminants at Camp Lejeune using ground water fate and transport and distribution system models (Maslia et al. 2007, 2013). The modeling provided monthly average estimates of the contaminant concentrations in drinking water delivered to study subject residences or workplaces from the Tarawa Terrace, Hadnot Point, and Holcomb Boulevard WTPs.

Exposure Assessment of Camp Lejeune Marines

We used unit code information from the DMDC database and historical information supplied by the DMDC and USMC that identified units stationed at either base to initially identify those stationed at Camp Lejeune and those stationed at Camp Pendleton. Base residential history information supplied by survey participants was then used to correct our initial assessment of base location. The DMDC data and base family housing records were

also used to make corrections to obvious errors in the survey responses such as incorrect dates when stationed at Camp Lejeune or family housing area.

To evaluate exposures to specific drinking water contaminants, residential locations needed to be determined. Therefore, we conducted a nested case-control sample of Marines at both bases that included confirmed cases of diseases of interest and a random sample of 3,000 Marines who did not report a cancer or non-cancer disease included in the questionnaire. Because of small numbers, female Marines without a reported disease of interest were oversampled for the control series. The sampling of controls was done in two stages to obtain a final sample of 3,000. First, a random sample of 2,600 was taken of all Marines who did not report a disease. Second, a random sample of 400 women was taken of all female Marines who did not report disease.

For cases or controls who reported that they lived at Camp Lejeune or did not specify on which base they lived, we used information from the residential history section of the survey and family housing records (for dependents and periods when active duty personnel were married). For periods when active duty personnel were single, residential location was determined by the survey information and by the unit identification codes in conjunction with information on the barrack location of each unit from command chronologies and from discussions with knowledgeable former Marines and current base staff.

If participants did not report specific residential or unit location information or their timeframe on base at Camp Lejeune, we searched for their name in the DMDC database to determine their marital status, unit, and time on base. To determine residence, we assumed that

1. unmarried enlisted Marines resided in barracks,
2. unmarried officers resided in bachelor officers' quarters, and
3. married Marines resided either in off-base housing or in base family housing.

If Marines were married and not found in the family housing records, we assumed they lived off base. If necessary, we also obtained residential information by searching the 1999-2002 ATSDR survey database for Marines, spouses, and children who participated in that survey.

The exposure assessment was based on the estimated contaminant levels in the drinking water serving the Marine's residence. Each month of residence was linked to the estimated levels of contaminants in the drinking water serving that location for that month. The participant's cumulative exposure (ppb-months) was calculated.

Exposure Assessment of Camp Lejeune civilian employees

For civilian employees, we used the codes for state, city and county in the DMDC personnel database to identify workers at Camp Lejeune and Camp Pendleton. Civilian workers were assumed to be employed at their respective bases during the entire quarter that they were listed in the DMDC database. Information obtained from Camp Lejeune current staff and retired base personnel indicated that most workplaces were located in the main area of the base served by the Hadnot Point water treatment plant. Therefore, we assumed that all civilian workers at Camp Lejeune received water from the Hadnot Point system at their workplaces. Cumulative, average, maximum and duration of exposure were calculated based on the estimated monthly average levels of the contaminants in the Hadnot Point distribution system during the period of employment at Camp Lejeune.

**Data Analysis**

We used unconditional logistic regression in SAS 9.3 statistical software (SAS) for all analyses to calculate odds ratios (ORs) and their 95% confidence intervals (CIs). Figure 1 shows the types of analyses conducted. We excluded those participants who reported a disease of interest but who did not provide information necessary to confirm the diagnosis.

Hodgkin lymphoma, non-Hodgkin lymphoma (NHL), and lymphomas with type unspecified were grouped together as "lymphoma" because the medical confirmation process was unable to distinguish the type of lymphoma for most of the reported cases. Since virtually all participants with a confirmed cancer of interest developed their cancers ten years or more after they were first stationed or worked at either base, we did not lag exposures or take into account a latency period.

In analyses of cumulative and average residential (Marines) or workplace (civilian workers) exposures to drinking water contaminants, we evaluated each contaminant separately as well as evaluating the sum of the amount of all the contaminants ("TVOC"). Marines and civilian employees were analyzed separately because their exposure scenarios differed. The primary exposure to drinking water contaminants for the Camp Lejeune workers was at the workplace. Camp Lejeune Marines could be exposed at their residences and during training and other activities on base.

Information reported in the survey on race; sex; education; age at survey, cancer diagnosis, or death; ever smoked cigarettes; and current number of alcoholic drinks was assessed for potential confounding. For Marines, rank, service in Vietnam, and potential occupational exposure, such as worked with pesticides, radiation, metals, solvents or

other chemicals, were also assessed. For civilian employees, we assessed those who worked as a cook or in food preparation, as a painter, in the laundry, in a blue collar job (e.g., maintenance, construction, sanitation), or with pesticides, radiation, solvents or polycyclic aromatic hydrocarbons.

Each cancer was adjusted for age at diagnosis when there were >2 cases per cell. Confounding by other risk factors was determined using a 10% change in the estimate rule (Maldonado et al. 1993). For cancers, two models were compared that included only those with complete information on the risk factor being evaluated: a model with the exposure variable and age at diagnosis, and a model that also included the risk factor. If the ORs for the exposure variable in the two models differed by ≥10%, then the risk factor was considered a confounder and was included in an adjusted model. For non-cancers, an unadjusted model that included only those with complete information on the risk factor being evaluated was compared to a model adjusted by the risk factor. If the ORs for the exposure variable in the two models differed by ≥10%, then the risk factor was considered a confounder and included in an adjusted model. If no risk factors were determined to be confounders using this 10% change in the estimate rule, then the unadjusted model was reported for a non-cancer, and a model adjusted for age at diagnosis (if there were >2 cases per cell) was reported for a cancer.

**Analysis of disease risk in Marines**

For comparisons of diseases between Camp Lejeune and Camp Pendleton Marines, we included all morbidity study participants. This analysis assumed that all Marines stationed at Camp Lejeune were exposed to the contaminated drinking water (if

not at their residence then during field training and other activities at the base). We used the case-control sample of Marines at both bases to evaluate cumulative contaminant-specific residential exposures. ATSDR also analyzed cumulative residential exposures restricted to the Camp Lejeune cases and controls.

For the categorical analyses of cumulative exposure to the contaminants using Camp Pendleton Marines as the referent exposure level, "low," "medium," and "high" exposure categories were evaluated based on cut points at the 50$^{th}$ and 90$^{th}$ percentiles, respectively, among the Camp Lejeune controls (Table 2). For female Marines, cut points were chosen based on the 75$^{th}$ ("medium") and 90$^{th}$ ("high") percentiles because the 50$^{th}$ percentile was 0 ppb for the contaminants. Some Camp Lejeune Marines in the low exposure category had no residential exposure to the contaminants. However, they likely were exposed to the drinking water contaminants during field training and other activities at the base.

**Analysis of disease risk in civilian employees**

All analyses for the Camp Lejeune and Camp Pendleton civilian workers included all workers in the morbidity study. For the categorical analyses of civilian workers using Camp Pendleton workers as the referent exposure level, we evaluated "low," "medium," and "high" cumulative exposures to the contaminants using cut points at the 50$^{th}$ and 90$^{th}$ percentiles based on the distributions of cumulative exposures among the Camp Lejeune workers who did not have a confirmed disease.

**Sensitivity analyses**

Response rates were defined as the number of completed surveys divided by the total number of individuals sampled for whom a current address was available (or for

their next of kin if deceased). Even though intensive methods were used to increase response rates and convert non-responders, non-response (or selection) bias was a concern. For non-response (or selection) bias to be present, participation rates must vary jointly by exposure and disease status. We evaluated whether participation rates varied among the Camp Lejeune and Camp Pendleton cohorts by risk factors such as age, race, sex, education level, and rank (Marines only) using data from the DMDC personnel databases. For those Camp Lejeune Marines who were included in the published mortality study (Bove et al. 2014a), we compared participants and non-participants on cumulative and average residential exposures to TCE, PCE, and TVOC.

To further evaluate the likelihood and magnitude of selection bias, we used two indirect methods. First, we compared results obtained using the Camp Pendleton cohorts as exposure referents with results obtained in analyses that evaluated cumulative exposures internal to the Camp Lejeune cohorts using cut points at the 50$^{th}$ and 90$^{th}$ percentiles. Internal analyses should be less affected by selection bias from non-participation in the survey because non-participation is unlikely to be associated with cumulative exposure. Second, in the Discussion section, we compare the results for confirmed diseases in this study with the results for these diseases in the published mortality studies at Camp Lejeune (Bove et al. 2014 a, b). Any differences might be evidence that selection bias was present in the current study, although they also could result from comparing results based on incidence data with results based on mortality data, especially for diseases that have high survival rates.

Confirming diagnoses should reduce information bias from over-reporting of conditions. However, confirmation was not possible for all reported conditions of

interest. Therefore, tables were provided that compared the percentages of completed HIPAA forms and medical record confirmation for each disease between the Camp Lejeune and Camp Pendleton cohorts.

**Interpretation of results**

As in our previously published Camp Lejeune studies, we did not use statistical significance testing to interpret results (Rothman et al. 2008, 2010; Stang et al. 2010). We did not want to make a qualitative decision about the importance of a result in this study based on using an arbitrary cutoff for "significance" (e.g., $p < 0.05$ or a 95% CI that does not include the null value) (Rothman et al. 2008). This is because a result that fails to achieve statistical significance can still provide potentially useful information, and a result that achieves statistical significance can lack scientific and public health significance (Porta 2014). Therefore, we agree with the recommendation on page 163 in Modern Epidemiology, 3rd edition that states "…Because statistical hypothesis testing promotes so much misinterpretation, we recommend avoiding its use in epidemiological presentations and research reports" (Rothman et al. 2008). Instead, we interpreted the results from this study based on the magnitude of the OR and consistency with results from other published studies (Hill 1965).

Although all ORs are provided in the tables, ORs ≥1.5 for cumulative exposures to TCE or PCE in the internal analyses for both Marines and civilian employees are highlighted in the Discussion section and summary table of key results (Table 21) according to the following hierarchy:

- The ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases (ATSDR 2017)

concluded that the evidence for causation for the disease and contaminant was at least "equipoise and above."

- If the 2017 ATSDR assessment concluded that the evidence was below equipoise, we did not highlight the disease-contaminant pair.
- If the 2017 ATSDR assessment did not evaluate the disease, then we checked if the result was supported by the previous mortality studies at Camp Lejeune (Bove et al. 2014a, b).

The decision to highlight ORs ≥1.5, although arbitrary, is supported by empirical studies indicating that confounding bias, if present, would change an effect estimate such as the OR by no more than 0.2 or 0.3 (Kriebel et al 2004, Blair et al 2007). Based on considerations of the impact of variability and confounding, one epidemiological text book considered ratio estimates of ≥1.5 as indicating a "moderate" strength of association (Monson, 1990).

We also indicate on Table 21 if there was a monotonic exposure-response relationship. Monotonic exposure-response relationships occur when every change in the OR with increasing category of exposure is in the same direction, although the trend could have flat segments but never reverse direction (Rothman et al. 2008). Although monotonic exposure-response relationships are highlighted, we recognize that exposure misclassification bias could have distorted exposure-response relationships, such as producing non-monotonic trends that attenuate or turn negative at higher exposure levels (Stayner et al. 2003). For the evaluation of exposure-response relationships, we focused on the analyses internal to the Camp Lejeune cohorts because selection bias (i.e., survey participation associated with exposure status) was less likely in these analyses.

**Presentation of results**

TCE was the main contaminant at Hadnot Point, and PCE was the main contaminant at Tarawa Terrace. The categorical variables for cumulative exposures among Camp Lejeune controls in the case-control sample were highly correlated. For example, there was complete correlation (gamma coefficient >0.99) between the categorical variable for TCE and the categorical variables for vinyl chloride, benzene and TVOC. The correlation between TCE and PCE was also very high (gamma coefficient = 0.88). Therefore, we only present results for TCE and PCE for the categorical analyses for Marines. Additionally, all civilian workplaces at Camp Lejeune were assumed to be at mainside and served by Hadnot Point drinking water. The correlation coefficient between the categorical variables for cumulative TCE and PCE exposures in civilian employees was 1.0. Because of that, we present results as TCE/PCE exposure for the categorical analyses for civilian employees using the $50^{th}$ and $90^{th}$ percentiles of cumulative TCE exposure among workers without a confirmed disease as the cut points. .

All ORs and their 95% CIs are provided in the tables. However, because the study hypotheses focused exclusively on the possible adverse health effects associated with exposure to contaminated drinking water at Camp Lejeune, only ORs >1.0 are identified in the Results section. Some ORs for specific diseases in the tables are <1.0 (e.g., for male infertility and lupus in the internal analyses of Camp Lejeune Marines). These ORs are interpreted as providing no support for our hypotheses that the exposures to contaminated drinking water at Camp Lejeune increased the risk for these diseases. We are not aware of any mechanism by which exposure to the chemicals in the drinking

water at Camp Lejeune could be considered protective for the specific adverse health outcomes evaluated in this study. ORs <1.0 may be due to biases including selection and exposure misclassification as well as random error due to small numbers for discrete endpoints.

The Results section also highlights when there were monotonic exposure-response relationships. ORs for specific subtypes of infertility and kidney and liver diseases are presented in the tables only. CIs are provided only to indicate the level of precision (or uncertainty) in the OR estimates. The wider the CI, the less precision and more uncertainty there is in the estimate of the OR. For the dependents at Camp Lejeune, only descriptive statistics were reported because we had no comparison cohort.

**RESULTS**

Of the 247,479 surveys that were sent to cohort members with accurate addresses, 76,057 surveys were completed for a response rate of 31% (Table 1). Among the surveys received, 77% were submitted on paper and 23% were submitted on-line. Marines from Camp Lejeune and Camp Pendleton had similar participation rates (30% vs. 28%, respectively). In contrast, civilian employees from Camp Lejeune participated at higher rates than those from Camp Pendleton (45% vs. 38%, respectively). The participation rate for the 1999-2002 ATSDR survey cohort was 36%. Surveys were completed by next-of-kin for 3,002 (4%) of the cohort who had died: 2,168 Camp Lejeune Marines, 459 Camp Pendleton Marines, 200 Camp Lejeune civilian employees, 137 Camp Pendleton civilian employees, and 38 Camp Lejeune Marines and dependents from the 1999-2002 ATSDR

survey.

HIPAA forms for diseases of interest were sent to 10,655 Marines from Camp Lejeune, 2,335 Marines from Camp Pendleton, 786 civilian employees from Camp Lejeune, 473 civilian employees from Camp Pendleton, and 1,585 persons in the 1999-2002 ATSDR survey cohort. Of these, HIPAA forms were completed by 56% of Camp Lejeune Marines, 51% of Camp Pendleton Marines, 66% of civilian employees from Camp Lejeune, 60% of civilian employees from Camp Pendleton, and 61% of persons in the previous ATSDR survey.

Generally, the cohorts had similar demographics. Prevalence of having ever smoked and current number of alcoholic drinks was similar between Marines at Camp Lejeune and Camp Pendleton (Table 3). Number of cigarettes smoked per day was missing for 69% of Camp Lejeune Marines and 71% of Camp Pendleton Marines. Of those who reported the number of cigarettes smoked per day, Marines from Camp Lejeune and Camp Pendleton reported smoking a similar number of cigarettes per day (30% each reported smoking up to half pack a day; 54% and 55%, respectively, reported smoking more than half a pack to a pack a day; 15% each reported smoking more than pack a day to less than two packs a day; and 1% each reported smoking more than two packs a day). Marines at Camp Lejeune and Camp Pendleton were also similar for number of years smoked. Notable differences among Marines included a higher percentage of African American Marines and fewer females at Camp Lejeune than at Camp Pendleton. Among civilian employees, more were African Americans and fewer were categorized as “other” race, and more females worked at Camp Lejeune than at Camp Pendleton (Table 4). The reported number of cigarettes smoked per day was

similar for Camp Lejeune and Camp Pendleton civilian employees.

All causes of cancer were adjusted for age at diagnosis if >2 cases per cell. For chemical-specific diseases in analyses comparing Camp Lejeune Marines with Camp Pendleton Marines, cancers and other diseases were also adjusted for sex if the outcome was not a sex-specific disease and it was reported in both sexes. Adjusting for ever smoked cigarettes and being a current drinker did not change the ORs for cancers of the lung or cancers that are likely to be affected by alcohol consumption by >10%, respectively. Therefore, these variables were not included in the final models. For example, ORs for lung cancer and high PCE exposure in Marines adjusted and not adjusted for ever smoked were 1.45 and 1.53, respectively; these ORs only differ by 5.2%. Table 2 provides the levels of contamination included in the exposure categories. Table 5 summarizes results of the cancers and other diseases evaluated by each cohort and type of analysis.

## Cancer

### Digestive organs

#### Colon

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for colon cancer was 1.36 (95% CI: 0.93, 1.97) (Table 6). For high residential exposures ($\geq 90^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.11 (95% CI: 0.62, 2.00) and 1.92 (95% CI: 1.16, 3.20), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, the OR for high residential exposure to TCE was ≤1.0 (Table 9) while the OR for high PCE exposure was 1.48 (95% CI: 1.01, 2.19) (Table 10).

The OR comparing civilian employees at Camp Lejeune to those at Camp

Pendleton was 1.49 (95% CI: 0.75, 2.96) for colon cancer (Table 11). The colon cancer OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 4.74 (95% CI: 1.77, 12.68), and the exposure-response relationship was monotonic (Table 12). For the analysis internal to Camp Lejeune civilian employees, the colon cancer OR for high TCE/PCE exposure was 5.47 (95% CI: 1.86, 16.1) with a monotonic exposure-response relationship (Table 13).

**Esophagus**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for esophageal cancer among men was 1.29 (95% CI: 0.56, 3.01) (Table 6). There were no cases of esophageal cancer among female Marines at either base. For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with Marines at Camp Pendleton, ORs were 1.55 (95% CI: 0.49, 4.90) and 1.94 (95% CI: 0.66, 5.70), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposure were 1.18 (95% CI: 0.47, 2.94) and 1.57 (95% CI: 0.70, 3.54), respectively (Tables 9 and 10). A monotonic exposure-response relationship was seen for TCE exposure with Camp Pendleton as the referent. ORs for esophageal cancer in civilian employees at Camp Lejeune compared with those at Camp Pendleton were ≤1.0 and could not be assessed in categorical analyses because of small numbers (Tables 11-13).

**Liver**

The ORs for liver cancer in analyses of Camp Lejeune Marines compared with Camp Pendleton Marines were ≤1.0 (Tables 6-8). For analyses internal to Camp Lejeune Marines, ORs for high residential exposures (≥90$^{th}$ percentile) to TCE and PCE were 1.17

(95% CI: 0.38, 3.54) and 1.26 (95% CI: 0.42, 3.84), respectively (Tables 9 and 10). ORs for liver cancer in civilian employees at Camp Lejeune compared with those at Camp Pendleton were ≤1.0 and could not be assessed in categorical analyses because of small numbers (Tables 11-13).

**Pancreas**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for pancreatic cancer was 2.26 (95% CI: 0.91, 5.62) (Table 6). ORs for high residential exposures (≥90$^{th}$ percentile) to PCE among Marines at Camp Lejeune compared with those at Camp Pendleton and in analyses internal to Camp Lejeune Marines were 2.67 (95% CI: 0.89, 7.98) and 1.35 (95% CI: 0.65, 2.77), respectively (Tables 8 and 10). ORs for TCE in these analyses were ≤1.0 (Tables 7 and 9).

The OR comparing civilian workers at Camp Lejeune with those at Camp Pendleton was ≤1.0 (Table 11). For high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE, the OR for civilian employees at Camp Lejeune compared with Camp Pendleton was 2.84 (95% CI: 0.73, 11.07) (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 12.48 (95% CI: 1.72, 90.46) based on 3 exposed cases, and the trend was monotonic (Table 13).

**Rectum**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for rectal cancer was 2.01 (95% CI: 0.81, 5.01) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 2.12 (95% CI: 0.65-6.85) and 2.38 (95% CI: 0.76, 7.45), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposure were both 1.4 (Tables 9 and 10). Monotonic exposure-

response relationships were seen for PCE in the analysis with Camp Pendleton as the referent and in the analysis internal to Camp Lejeune.

The OR comparing civilian employees at Camp Lejeune to those at Camp Pendleton was 1.41 (95% CI: 0.35, 5.65) for rectal cancer (Table 11). The OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 6.62 (95% CI: 1.33, 33.04) (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 7.11 (95% CI: 1.18, 42.9) (Table 13). ORs for workplace exposure to TCE/PCE were based on three cases with high exposure.

**Hematopoietic**

**Leukemia**

ORs for leukemia in Camp Lejeune Marines compared with Camp Pendleton Marines and for the categorical analyses of Marines were ≤1.0 (Tables 6-10). The OR for leukemia comparing civilian employees at Camp Lejeune to those at Camp Pendleton was 1.10 (95% CI: 0.36, 3.38) (Table 11). The OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 1.32 (95% CI: 0.15, 11.40) based on 1 case with high exposure (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 1.58 (95% CI: 0.16, 15.3) based on 1 case with high exposure (Table 13).

**Lymphomas**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for lymphoma was 1.06 (95% CI: 0.75, 1.50) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE, ORs for lymphomas in the categorical analyses of Marines

were ≤1.0 (Tables 7 and 9). For high residential exposures (≥90$^{th}$ percentile) to PCE, ORs in the analysis of Camp Lejeune Marines compared with Camp Pendleton Marines and the analysis internal to Camp Lejeune Marines were 1.01 (95% CI: 0.8, 10.54) and 1.14 (95% CI: 0.71, 1.84), respectively (Tables 8 and 10). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.28 (95% CI: 0.59, 2.79) for lymphoma (Table 11). The OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 1.71 (95% CI: 0.46, 6.39) (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 1.86 (95% CI: 0.43, 8.11) (Table 13). ORs for workplace exposure to TCE/PCE were based on three cases with high exposure.

**Multiple Myeloma**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for multiple myeloma in men only was 2.06 (95% CI: 0.74, 5.71) (Table 6). There were no cases among female Marines or workers. For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.12 (95% CI: 0.20, 6.20) and 2.93 (95% CI: 0.55, 7.19), respectively (Tables 7 and 8); however, there was only 1 case with high TCE exposure. For analyses internal to Camp Lejeune Marines, the OR for high PCE exposure was 1.35 (95% CI: 0.54, 3.40), but the OR for high TCE exposure was ≤1.0 (Tables 9 and 10). Monotonic exposure-response relationships were seen for PCE in the analysis with Camp Pendleton as the referent and in the analysis internal to Camp Lejeune.

The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.57 (95% CI: 0.29, 8.62) for multiple myeloma (Table 11), based on 2

cases at Camp Lejeune. The OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 3.31 (95% CI: 0.30, 36.68) based on 1 case with high exposure (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 2.72 (95% CI: 0.17, 43.8) (Table 13), based on one case with high exposure.

**Respiratory**

**Larynx**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for laryngeal cancer was 2.28 (95% CI: 0.71, 7.38) (Table 6). ORs for high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton were 2.12 (95% CI: 0.46, 9.75) and 4.04 (95% CI: 1.06, 15.34), respectively. The exposure-response relationship was monotonic for PCE (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, the OR for high residential exposures (≥90$^{th}$ percentile) to TCE and PCE was 1.62 (95% CI: 0.52, 5.10) and 3.26 (95% CI: 1.37, 7.72), respectively (Tables 9 and 10). The exposure-response relationship was monotonic for PCE. The OR comparing civilian workers at Camp Lejeune with those at Camp Pendleton was 1.42 (95% CI: 0.13, 15.73) based on two exposed cases (Table 11). ORs for laryngeal cancer and the categorical analyses in civilian employees at Camp Lejeune could not be assessed because of small numbers (Tables 12 and 13).

**Lung**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for lung cancer was 1.43 (95% CI: 1.01, 2.02) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, the OR was 1.62 (95% CI: 1.00-2.62) (Table 8). For the analysis internal to

Camp Lejeune Marines, the OR for high PCE exposure was 1.23 (95% CI: 0.84, 1.78) (Table 10). ORs for high TCE exposure in the analysis comparing Camp Lejeune Marines to those at Camp Pendleton and the internal analysis of Camp Lejeune Marines were ≤1.0 (Tables 7 and 9). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.59 (95% CI: 0.91, 2.80) for lung cancer (Table 11). The OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 1.50 (95% CI: 0.55-4.11) (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 1.10 (95% CI: 0.38, 3.22) (Table 13).

**Sex-specific**

**Breast (male)**

ORs for male breast cancer could not be evaluated in analyses of Camp Lejeune Marines compared with Camp Pendleton Marines because there were no cases at Camp Pendleton (Table 6). For analyses internal to Camp Lejeune Marines, the OR for high PCE exposure was 1.26 (95% CI: 0.14, 11.3) based on 1 case with high exposure (Table 10), but the OR for high TCE exposure was ≤1.0 (Table 9). ORs for male breast cancer in civilian employees at Camp Lejeune were ≤1.0 in analysis comparing those at Camp Lejeune with those at Camp Pendleton and could not be assessed in categorical analyses because of small numbers (Tables 11-13).

**Breast (female)**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for female breast cancer was 1.05 (95% CI: 0.75, 1.47) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.40 (95% CI: 0.67, 2.91) and 1.64 (95% CI: 0.78, 3.44), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune

Marines, ORs for high TCE and PCE exposure were 1.27 (95%CI: 0.62, 2.59) and 1.51 (95% CI: 0.73, 3.09), respectively (Tables 9 and 10).

The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 2.09 (95% CI: 1.34, 3.26) for female breast cancer (Table 11). ORs for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE in analyses comparing civilian employees at Camp Lejeune with those at Camp Pendleton and the analysis internal to Camp Lejeune civilian employees were both 5.09, and both had monotonic exposure-response relationships (Tables 12 and 13).

**Cervix**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for cervical cancer was 2.01 (95% CI: 0.68, 6.00) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 3.25 (95% CI: 0.57, 18.43) and 1.63 (95% CI: 0.18, 14.97), respectively, but these were based on 1 or 2 cases with high exposure (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, the OR for TCE was 1.06 (95% CI: 0.23, 4.86) based on 2 cases with high exposure (Tables 9) while the OR for PCE was ≤1.0 (Table 10). ORs for cervical cancer in civilian employees at Camp Lejeune were ≤1.0 in the analysis comparing those at Camp Lejeune with those at Camp Pendleton and could not be assessed in categorical analyses because of small numbers (Tables 11-13).

**Prostate**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for prostate cancer was 1.23 (95% CI: 1.01, 1.50) (Table 6). ORs for high PCE exposure (≥90$^{th}$ percentile) in the analysis comparing Camp Lejeune Marines to those at Camp Pendleton and the internal analysis of Camp Lejeune Marines were 1.62 (95% CI: 1.18,

2.23) and 1.37 (95% CI: 1.06, 1.76), respectively (Tables 8 and 10); ORs for high TCE exposure in these analyses were ≤1.0 (Tables 7 and 9).

The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.28 (95% CI: 0.87, 1.89) for prostate cancer (Table 11). ORs for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE in the analysis comparing civilian employees at Camp Lejeune with those at Camp Pendleton and the analysis internal to Camp Lejeune civilian employees were both 2.4 (95% CI: 1.43-4.02 for the analysis with Camp Pendleton as the referent and 95% CI: 1.32-4.44 for the internal analysis) with a monotonic exposure-response relationship observed in the internal analysis (Tables 12 and 13).

**Urinary**

**Bladder**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for bladder cancer was 1.64 (95% CI: 1.02, 2.64) (Table 6). ORs for high PCE exposure (≥90$^{th}$ percentile) in the analysis comparing Camp Lejeune Marines to Camp Pendleton Marines and the internal analysis of Camp Lejeune Marines were 2.07 (95% CI: 1.12, 3.82) and 1.54 (95% CI: 0.99, 2.41), respectively (Tables 8 and 10). ORs for high TCE exposure in these analyses were ≤1.0 (Tables 7 and 9). The OR comparing civilian workers at Camp Lejeune with those at Camp Pendleton was ≤1.0 (Table 11). However, ORs for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE in the analysis comparing civilian employees at Camp Lejeune with those at Camp Pendleton and the analysis internal to Camp Lejeune civilian employees were both 1.8 (95% CI: 0.50-6.53 for the analysis with Camp Pendleton as the referent and 0.47-6.77 for the internal analysis) based on 3 cases with high exposure (Tables 12 and 13).

**Kidney**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for kidney cancer was 1.31 (95% CI: 0.86, 1.99) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.42 (95% CI: 0.78, 2.58) and 1.79 (95% CI: 1.02, 3.12), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposure were 1.55 (95% CI: 0.95, 2.54) and 2.01 (95% CI: 1.29, 3.13) respectively, and monotonic exposure-response relationships were observed (Tables 9 and 10).

The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.52 (95% CI: 0.69, 3.35) for kidney cancer (Table 11). The OR for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton was 13.92 (95% CI: 5.09, 38.10) (Table 12). For the analysis internal to Camp Lejeune civilian employees, the OR for high TCE/PCE exposure was 41.5 (95% CI: 10.2, 169.23), and a monotonic exposure-response relationship was observed (Table 13).

**Other**

**Brain**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for brain cancer was 1.07 (95% CI: 0.61, 1.89) (Table 6). ORs for high PCE exposure (≥90$^{th}$ percentile) in the analysis comparing Camp Lejeune Marines to those at Camp Pendleton and the internal analysis of Camp Lejeune Marines were 1.33 (95% CI: 0.58, 3.05) and 1.46 (95% CI: 0.73, 2.92), respectively. A monotonic exposure-response relationship was observed in the internal analysis (Tables 8 and 10). ORs for high TCE exposure in these analyses were ≤1.0 (Tables 7 and 9).

The OR comparing civilian workers at Camp Lejeune with those at Camp Pendleton was 4.01 (95% CI: 0.48, 33.38) (Table 11). ORs for brain cancer and categorical analyses of exposure in civilian employees at Camp Lejeune could not be assessed because of small numbers (Tables 12 and 13).

**Pharynx**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for pharyngeal cancer was 1.29 (95% CI: 0.62, 2.70) (Table 6). ORs for high TCE exposure ($\geq 90^{th}$ percentile) in the analysis comparing Camp Lejeune Marines with those at Camp Pendleton and the internal analysis of Camp Lejeune Marines were 1.34 (95% CI: 0.49, 3.65) and 1.59 (95% CI: 0.69, 3.66) (Tables 7 and 9); ORs for high PCE exposure in these analyses were $\leq 1.0$ (Tables 8 and 10). ORs for pharyngeal cancer could not be evaluated in civilian employees because there were no cases at Camp Pendleton and only two cases at Camp Lejeune (Tables 11 and 12).

**Soft tissue**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for soft tissue cancer was 1.27 (95% CI: 0.54, 2.97) (Table 6). For high residential exposures ($\geq 90^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.33 (95% CI: 0.42, 4.23) and 1.88 (95% CI: 0.63, 5.57), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposure were 1.42 (95% CI: 0.56, 3.63) and 2.15 (95% CI: 0.92, 5.03), respectively, and the exposure-response relationships were monotonic (Tables 9 and 10). ORs for soft tissue cancer could not be evaluated in civilian employees because there were no cases at Camp Pendleton and only two cases at Camp Lejeune (Tables 11 and 12).

## Non-cancer diseases

### Autoimmune diseases

**Lupus**

The OR for the analysis comparing Camp Lejeune Marines with Camp Pendleton Marines was 1.50 (95% CI: 0.80-2.83) (Table 6). For the analyses comparing high residential exposures (≥90th percentile) to TCE and PCE among Marines at Camp Lejeune with those at Camp Pendleton, the ORs were 1.46 (95% CI: 0.53, 4.04) and 1.50 (95% CI: 0.54-4.18), respectively (Tables 7-8). ORs for high residential exposures (≥90th percentile) to TCE and PCE were ≤1.0 in the internal analyses of Camp Lejeune Marines (Tables 9 and 10). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 2.44 (95% CI: 0.51, 11.77) for lupus (Table 11). ORs for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton and the analysis internal to Camp Lejeune were 3.31 (95% CI: 0.30, 36.68) and 4.74 (95% CI: 0.30, 76.10), respectively, based on 1 case with high exposure (Tables 12 and 13).

**Scleroderma**

ORs for scleroderma in the analysis of Camp Lejeune Marines compared with Camp Pendleton Marines and in the categorical analyses of Marines were ≤1.0 (Tables 6-10). The OR comparing civilian workers at Camp Lejeune with those at Camp Pendleton was 1.40 (95% CI: 0.13, 15.40) based on two exposed cases (Table 11). ORs for scleroderma and the categorical analyses of civilian employees could not be assessed because of small numbers (Tables 12 and 13).

### Nervous system

**ALS**

The OR for ALS in analysis of Camp Lejeune Marines compared with Camp Pendleton Marines was ≤1.0 (Tables 6). For high residential exposures (≥90$^{th}$ percentile)

to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.13 (95% CI: 0.38, 3.34) and 1.86 (95% CI: 0.71, 4.85), respectively (Tables 7 and 8). There were no female cases of ALS among Camp Lejeune Marines. For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposure among men were 1.67 (95% CI: 0.65, 4.25) and 2.63 (95% CI: 1.21, 5.73), respectively (Tables 9 and 10). ALS could not be evaluated in civilian employees because there were no cases at Camp Lejeune (Table 11).

**MS**

The OR for MS in analysis of Camp Lejeune Marines compared with Camp Pendleton Marines was 1.19 (95% CI: 0.74, 1.90) (Tables 6). For high residential exposures ($\geq 90^{th}$ percentile) to TCE among Marines at Camp Lejeune compared with those at Camp Pendleton and in the analysis internal to Camp Lejeune, ORs were 1.70 (95% CI: 0.86, 3.36) and 1.46 (95% CI: 0.82, 2.59), respectively, and exposure-response relationships were monotonic (Table 7 and 9). ORs for PCE were ≤1.0 in these analyses (Tables 8 and 10). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 4.88 (95% CI: 0.60, 39.75) for MS (Table 11). ORs for high workplace exposures ($\geq 90^{th}$ percentile) to TCE//PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton and the analysis internal to Camp Lejeune civilian employees were 6.62 (95% CI: 0.41, 106.28) and 1.58 (95% CI: 0.16, 15.3), respectively, based on 1 case with high exposure, and exposure-response relationships were monotonic (Tables 12 and 13).

**Parkinson disease**

ORs for Parkinson disease were ≤1.0 in the analysis comparing Camp Lejeune Marines with Camp Pendleton Marines, the analysis comparing high residential

exposures (≥90th percentile) to TCE among Marines at Camp Lejeune with those at Camp Pendleton and the internal analysis of high TCE exposure among Camp Lejeune Marines (Tables 6, 7, and 9). ORs for high residential exposures (≥90$^{th}$ percentile) to PCE among Marines at Camp Lejeune compared with those at Camp Pendleton and in the analysis internal to Camp Lejeune Marines were 1.22 (95% CI: 0.57, 2.61) and 1.32 (95% CI: 0.70, 2.49), respectively (Tables 8 and 10). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 3.11 (95% CI: 1.16, 8.32) for Parkinson disease (Table 11). ORs for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton and the analysis internal to Camp Lejeune were 2.86 (95% CI: 0.67, 12.13) and 2.03 (95% CI: 0.52, 7.93), respectively, based on 3 cases with high exposure (Tables 12 and 13).

## Reproductive organs

### Male infertility

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for male infertility was 2.74 (95% CI: 1.28, 5.87) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were both 2.31 (95% CI: 0.88, 6.05) (Tables 7 and 8). ORs were ≤1.0 in analyses internal to Camp Lejeune Marines (Tables 9 and 10). ORs for male infertility could not be evaluated in civilian employees because there were no cases at Camp Pendleton and only two cases at Camp Lejeune (Tables 11 and 12).

### Female infertility

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for female infertility was 1.39 (95% CI: 0.98, 1.99) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with

those at Camp Pendleton, ORs were 1.73 (95% CI: 0.83, 3.60) and 1.59 (95% CI: 0.75, 3.37), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, the OR for high TCE exposure was 1.10 (95% CI: 0.54, 2.22) and the OR for PCE was 1.07 (95% CI: 0.52, 2.22) (Tables 9 and 10). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 2.08 (95% CI: 1.02, 4.23) for female infertility (Table 11). ORs were ≤1.0 for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton and for the analysis internal to Camp Lejeune (Tables 12 and 13).

**Endometriosis**

For Camp Lejeune Marines compared with Camp Pendleton Marines, the OR for endometriosis was 1.29 (95% CI: 0.88, 1.89) (Table 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.83 (95% CI: 0.86, 3.92) and 1.67 (95% CI: 0.76, 3.65), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposure were 1.29 (95% CI: 0.62, 2.70) and 1.26 (95% CI: 0.57, 2.69), respectively (Tables 9 and 10). The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.83 (95% CI: 0.89, 3.77) (Table 11). ORs were ≤1.0 for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton and for the analysis internal to Camp Lejeune (Tables 12 and 13).

**Other**

**Aplastic anemia**

The OR for aplastic anemia in the analysis of Camp Lejeune Marines compared with Camp Pendleton Marines was ≤1.0 (Table 6). ORs for high PCE exposure (≥90$^{th}$ percentile) in the analysis comparing Camp Lejeune Marines with those at Camp

Pendleton and for the internal analysis of Camp Lejeune Marines were 1.28 (95% CI: 0.33, 4.94) and 1.74 (95% CI: 0.54, 5.59), respectively (Tables 8 and 10). The exposure-response relationship was monotonic in the internal analysis. ORs for high TCE exposure in these analyses were ≤1.0 (Tables 7 and 9). ORs for aplastic anemia could not be evaluated in analyses of Camp Lejeune civilian employees because there were no cases at Camp Pendleton and only two cases at Camp Lejeune (Tables 11 and 12).

**Kidney disease**

The OR for kidney disease in the analysis of Camp Lejeune Marines compared with Camp Pendleton Marines was 1.70 (95% CI: 1.14, 2.52) (Tables 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.43 (95% CI: 0.81, 2.52) and 2.00 (95% CI: 1.18, 3.39), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, ORs for high TCE and PCE exposures were 1.03 (95% CI: 0.66, 1.62) and 1.51 (95% CI: 1.02, 2.26), respectively (Tables 9 and 10). Monotonic exposure-response relationships for PCE were observed in the comparison with Camp Pendleton Marines and the analysis internal to Camp Lejeune Marines. The OR comparing civilian employees at Camp Lejeune with those at Camp Pendleton was 1.19 (95% CI: 0.54, 2.60) for kidney disease (Table 11). ORs for high workplace exposures (≥90$^{th}$ percentile) to TCE/PCE among civilian employees at Camp Lejeune compared with those at Camp Pendleton and the analysis internal to Camp Lejeune were 2.65 (95% CI: 0.82, 8.53) and 4.74 (95% CI: 1.18, 19.10), respectively (Tables 12 and 13). A monotonic exposure-response relationship was observed in the internal analysis.

**Liver disease**

The OR for liver disease in the analysis of Camp Lejeune Marines compared with

Camp Pendleton Marines was 1.42 (95% CI: 1.07, 1.88) (Tables 6). For high residential exposures (≥90$^{th}$ percentile) to TCE and PCE among Marines at Camp Lejeune compared with those at Camp Pendleton, ORs were 1.36 (95% CI: 0.89, 2.07) and 1.56 (95% CI: 1.03, 2.35), respectively (Tables 7 and 8). For analyses internal to Camp Lejeune Marines, the ORs for high TCE and PCE exposure were 1.15 (95% CI: 0.81, 1.62) and 1.29 (95% CI: 0.93, 1.79) (Tables 9 and 10). Monotonic exposure-response relationships for PCE were observed in the comparison with Camp Pendleton Marines and the analysis internal to Camp Lejeune Marines. The OR comparing civilian workers at Camp Lejeune with those at Camp Pendleton was 1.08 (95% CI: 0.50, 2.31) (Table 11). ORs for liver disease and categorical analyses of TCE/PCE exposure in civilian employees were ≤1.0 Tables 12 and 13).

**TCE-related skin disorder**

ORs for TCE-related skin disorders could not be evaluated because there were no cases at Camp Pendleton in Marines or civilian employees and no cases with high exposure at Camp Lejeune among Marines or civilian employees (Tables 6, 11).

**Sensitivity Analyses of Marines/Navy and Civilian Employee Cohorts**

When comparing participants and non-participants on characteristics available from the DMDC data, Marine and civilian employee participants were more educated, more likely to be white, and older. Marine participants also tended to have held a higher rank than non-participants (Table 14). When we compared the estimated exposures for those Marines in the mortality study who were participants in the morbidity study with those who did not participate, the mean duration of exposure was similar (approximately 1 year) (Table 15). Although participants had slightly higher median cumulative exposures (µg/L-months) than non-participants for TCE (1,134 versus 1,082) and PCE

(64 versus 57), their exposure intensities were similar. When cumulative exposures in the morbidity study were categorized using the cut points from the mortality study, the distributions between participants and non-participants were almost identical. Therefore, exposures were similar for participants and non-participant Marines who were included in the mortality study.

We compared the percentages of completed HIPAA forms and medical record confirmation by diseases between the cohorts (Tables 16 and 17). For the majority of diseases, the Camp Lejeune cohorts had higher percentages of completed HIPAA forms and medical record confirmations than did the Camp Pendleton cohorts. For comparisons using Camp Pendleton as the referent, we did not conduct sensitivity analyses that combined self-reported cases for which HIPAA forms were not received with confirmed diseases because there is a possibility of introducing both selection bias and information bias. For comparisons internal to Camp Lejeune, we did not conduct sensitivity analyses that combined self-reported cases for which HIPAA forms were not received with confirmed diseases because of the need to review thousands of records to be able to assign exposure.

**1999-2002 ATSDR Survey Cohort**

Data from the 1999-2002 ATSDR survey cohort could only be analyzed descriptively because no comparison group was available and numbers of cases were too small to conduct internal analyses. Data are presented separately for dependent children and adults (spouses and Camp Lejeune Marines who were not stationed at the base after March 1975) because their exposures were different. Most of the dependent children and adults from the previous survey were white, female, and high school graduates (Tables 18

and 19). Given that the dependent children were all ≤43 years of age at the time of the survey, very few cancers and other diseases of interest had occurred in this cohort. The largest number of confirmed cancers in dependent children was 6 (0.4%) lymphomas and the largest numbers of confirmed non-cancer diseases were 71 (7.3%) cases of female infertility, 42 (4.3%) cases of endometriosis, 14 (1.4%) cases of ovulation disorders, and 10 (0.6%) cases of liver disease. Among the adults in the 1999-2002 ATSDR survey cohort, the largest numbers of confirmed cancers were female breast (n=108, 4.4%) and prostate (n=76, 6.7%) and the largest number of confirmed non-cancer diseases was endometriosis (n=59, 2.4%).

**DISCUSSION**

ORs for several cancers and other diseases were higher in Camp Lejeune Marines and civilian employees with higher residential or workplace exposures to TCE or PCE compared with Camp Lejeune Marines and civilian employees with lower exposures. Table 20 compares the results of the internal analyses of the morbidity study with the 16 diseases that were included in the report "ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases" (ATSDR 2017). Table 20 also includes the results of the previous Camp Lejeune mortality studies (Bove et al. 2014a, b).

ORs ≥1.5 for cumulative exposures to TCE or PCE in the internal analyses for both Marines and civilian employees are highlighted in Table 21 according to the following hierarchy:

- The ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases (ATSDR 2017)

concluded that the evidence for causation for the disease and contaminant was at least "equipoise and above."

- If the 2017 ATSDR assessment concluded that the evidence was below equipoise, we did not highlight the disease-contaminant pair.
- If the 2017 ATSDR assessment did not evaluate the disease, then we checked if the result was supported by the previous mortality studies at Camp Lejeune (Bove et al. 2014a, b).

We also indicate on Table 21 if there was a monotonic exposure-response relationship. In the discussion, we focus on the results of the internal analyses of Camp Lejeune Marines and civilian employees from the morbidity study because they are likely less prone to selection bias. We considered ORs ≥1.5 for a particular disease in the morbidity study to be supported by the ATSDR assessment if the assessment concluded that the evidence for causation was at least "equipoise and above" (ATSDR 2017). Equipoise means at least as likely as not. We considered ORs ≥1.5 for a particular disease in the morbidity study to be supported by the mortality studies if the HRs were ≥1.5 (Bove et al. 2014a, b).

For bladder cancer, ORs of 1.54 (95% CI: 0.99, 2.41) and 1.78 (95% CI: 0.47, 6.77) were observed in the morbidity study for high PCE exposure for Marines and high TCE/PCE exposure in civilian employees, respectively. Small numbers of cases with high exposure among civilian employees resulted in wide CIs indicating considerable uncertainty in the OR estimate. These results are supported by the ATSDR assessment which concluded that the evidence for causation for PCE was sufficient.

For kidney cancer, the OR of 2.0 (95% CI: 1.3, 3.1) and monotonic exposure-response relationship for TCE in the morbidity study analyses of Marines and civilian

employees are supported by the ATSDR assessment and the assessments of other agencies, that there is sufficient evidence that TCE causes kidney cancer (EPA 2011; IARC 2014; NTP 2015; ATSDR 2017). The results are also supported by the results for TCE in the mortality study of Marines (Bove et al 2014a). The OR and monotonic exposure-response relationship for PCE in the internal analysis of Marines in the morbidity study is supported by the results for PCE in the mortality study of Marines at Camp Lejeune (Bove et al. 2014a). The ATSDR assessment concluded that the overall evidence linking PCE exposures and kidney cancer was below equipoise (or less likely than not). However, an occupational case-control study published after the ATSDR Assessment reported an OR of 3.0 (95% CI: 0.99, 9.0) for kidney cancer among those with high PCE exposure intensity and high cumulative exposure after excluding those with ≥50% probability of TCE exposure (Purdue et al. 2017).

ORs of 1.51 (95% CI: 1.02, 2.26) and 4.74 (95% CI: 1.18, 19.10) and monotonic exposure-response relationships were observed for kidney disease and PCE exposure among Marines and TCE/PCE exposure among civilian employees, respectively, in the morbidity study. These results are supported by the ATSDR assessment which concluded that the evidence for causality was equipoise and above for TCE and PCE (ATSDR 2017).

Although ORs for Parkinson disease and TCE and PCE in Marines were <1.5, an OR of 2.0 (0.5, 7.9) for high TCE/PCE exposure in civilian employees was observed with a monotonic exposure-response relationship. The OR in civilian employees was based on three cases with high exposure resulting in a wide CI indicating considerable uncertainty in the OR estimate. The result in civilian employees is supported by the ATSDR

assessment which concluded that the evidence for causality for TCE was equipoise and above and by the TCE result in the mortality study of civilian employees (ATSDR 2017; Bove et al 2014b). TCE has been found to be a mitochondrial neurotoxin in animal studies, and mitochondrial dysfunctions in substantia nigra dopamine neurons is consistent with human pathological staging of Parkinson disease (ATSDR 2017, Gash et al. 2008, Goldman et al. 2012, Zaheer and Slevin 2011). Few cases of Parkinson disease in Camp Lejeune Marines who are younger ages led to problems with sparse data. In the morbidity study, 93% of Marines and 51% of civilian employees were < 65 years of age. Parkinson disease is mostly diagnosed in persons age ≥65 years with peak incidence among persons aged 70-79 years (Hirsch et al. 2016). Parkinson disease can be categorized as early on-set or late on-set. Early on-set Parkinson disease occurs in persons 21-<50 years of age and accounts for about 10% of those diagnosed with the disease. Genetics play a role in early on-set of Parkinson disease with the increased likelihood of a family history of Parkinson disease in patients with early on-set compared with both the general population and patients with late-onset (Schrag and Schott 2006; van der Merwe et al. 2012). Old age is a major risk factor for Parkinson disease, and incidence drastically increases after age 65. In the health survey, 49% of civilian employees were age 65 or older compared with 7% of Marines being age 65 or older.

**LIMITATIONS**

The study has several major limitations. Surveys could not be sent to 20% of the cohort due to lack of complete and accurate addresses for mailing a survey. Additionally, some of the surveys coded as "not returned" likely did not reach the intended recipient. Intensive methods were used to increase participation rates and convert non-responders,

including Dillman's Tailored Design Method for mailed surveys and inserting in the mailings a letter signed by the highest ranking USMC officer encouraging participation. The low response rate in this survey is not uncommon and is consistent with a mailed survey of the Millennium Cohort (256,400 sampled from U.S. military personnel) which achieved a response rate of about 36% (Ryan et al. 2007). Nevertheless, selection biases are still a concern because of the low participation rate and past media coverage that increased awareness among former Marines, civilian employees, and dependents from Camp Lejeune of the drinking water contamination issue and of possible health problems from the exposures.

By confirming diagnoses, we minimized information bias from over-reporting of conditions. However, about 50% of Marines and 40% of civilian employees did not complete a HIPAA form to allow for medical confirmation which reduced the precision of the odds ratio estimates. Differences in participation rates in the medical confirmation aspect of the study also likely resulted in selection bias for the comparisons between Camp Lejeune and Camp Pendleton.

In the categorical analyses, there were small numbers of cases for some of the diseases in the exposure categories especially for civilian employees. Therefore, CIs were wide and these results need to be interpreted cautiously. When Camp Pendleton was used as the referent and the analysis produced different results than the internal analyses, this was possibly a result of selection bias.

There were several sources of exposure misclassification for the analyses of exposure-response trends for specific contaminants. There was uncertainty in determining a unit's barrack location because of limited information from command chronologies and

the need to rely to some extent on the recollections of knowledgeable former Marines and current base staff. We did not collect information on water consumption and use, the main source of exposure because of the time lapse between the period of exposure and when the survey was conducted. Exposure misclassification could also have resulted because of uncertainty about base assignments and the inability to accurately capture time spent away from the base for training or deployment. Although some Camp Lejeune Marines in the low exposure category probably had no residential exposure to the contaminants, they likely were exposed to the drinking water contaminants during field training and other activities at the base. There were also uncertainties and variabilities concerning the amount of water each individual routinely consumed (i.e., by ingestion, inhalation and dermal routes), the source of water in the field, the amount of time an individual routinely spent outside the base or in other parts of the base besides the residence or workplace. There was uncertainty, due to very limited historical information, about the locations of all the workplaces at Camp Lejeune (e.g., during the workday, a worker may have been assigned to multiple locations at the base). We assumed that all civilian employees worked on mainside and were served by the Hadnot Point drinking water system and that all civilian employees consumed drinking water while on base. Non-differential exposure misclassification can distort exposure-response relationships and produce non-monotonic trends that attenuate or turn negative at higher exposure levels (Stayner et al. 2003). In addition, categorization of a continuous exposure variable (e.g., cumulative exposure) can result in differential exposure misclassification that distorts exposure-response relationships by biasing effect estimates (e.g., odds ratios) towards or away from the null value.

We were unable to quantify associations in dependents because of a lack of an appropriate comparison group.

## CONCLUSIONS

The morbidity study found that contaminated drinking water at Camp Lejeune was associated with increased risk in both Marines and civilian employees for bladder cancer, kidney cancer, and kidney disease and that these results were informed by evidence from other studies For bladder cancer, ORs were ≥1.5 for PCE in Marines and for TCE/PCE in civilian employees, and results for PCE were supported by the ATSDR assessment (ATSDR 2017). For kidney cancer, ORs were ≥1.5 for both TCE and PCE in Marines and for TCE/PCE in civilian employees; results for TCE were supported by the ATSDR assessment (ATSDR 2017) and for both TCE and PCE in the previous Marine mortality study at Camp Lejeune (Bove et al. 2014a); and monotonic exposure-response relationships were observed for both TCE and PCE in Marines and for TCE/PCE in civilian employees. For kidney disease, ORs were ≥1.5 for PCE in Marines and for TCE/PCE in civilian employees; both TCE and PCE results were supported by the ATSDR assessment (ATSDR 2017); and monotonic exposure-response relationships were observed for PCE in Marines and for TCE/PCE in civilian employees.

Study results add to the scientific literature and suggest possible associations between the chemicals in the drinking water at Camp Lejeune and these diseases. Given the major limitations of this study, including response rate and possible selection bias, ATSDR is conducting additional research of the Camp Lejeune cohorts using data from cancer registries to evaluate cancer incidence.

**ACKNOWLEDGEMENT**

The authors thank the survey participants for taking time to fill out the survey and provide requested documentation. The authors also thank the following cancer registries for providing data for this study: California, Florida, Georgia, Indiana, Michigan, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and the Department of Veterans Affairs.

**Ohio**

Cancer incidence data used in these analyses were obtained from the Ohio Cancer Incidence Surveillance System (OCISS), Ohio Department of Health (ODH), a cancer registry partially supported by the National Program of Cancer Registries at the Centers for Disease Control and Prevention (CDC) through Cooperative Agreement Number NU58DP006284. Use of these data does not imply that ODH or CDC agrees or disagrees with the analyses, interpretations or conclusions in this report (or publication/presentation).

**Pennsylvania**

These data were supplied by the Bureau of Health Statistics & Research, Pennsylvania Department of Health, Harrisburg, Pennsylvania. The Pennsylvania Department of Health specifically disclaims responsibility for any analyses, interpretations or conclusions.

## REFERENCES

Abdullah R, Basak I, Patil KS, Alves G, Larsen JP, Møller SG. Parkinson's disease and age: The obvious but largely unexplored link. Exp Gerontol. 2015;68:33-8.

Agency for Toxic Substances and Disease Registry (ATSDR). Public Health Assessment: Marine Corps Base (MCB) Camp Pendleton, San Diego County, California. Atlanta: U.S. Department of Health and Human Services; September 2, 2008.

Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases. Atlanta: U.S. Department of Health and Human Services; January 13, 2017.

Aschengrau A, Ozonoff D, Paulu C, Coogan P, Vezina R, Heeren T, Zhang Y. Cancer risk and tetrachloroethylene-contaminated drinking water in Massachusetts. Arch Environ Health 1993; 48:284-92.

Aschengrau A, Rogers S, Ozonoff D. Perchloroethylene-Contaminated Drinking Water and the Risk of Breast Cancer: Additional Results from Cape Cod, Massachusetts, USA. Environ Health Perspect. 2003;111(2):167-73.

Blair A, Stewart P, Lubin JH, Forastiere F. Methodological issues regarding confounding and exposure misclassification in epidemiological studies of occupational exposures. Am J Ind Med 2007;50:199-207.

Bove FJ, Ruckart PZ. An Assessment of the Feasibility of Conducting Future Epidemiological Studies at USMC Base Camp Lejeune. 2008. http://www.atsdr.cdc.gov/sites/lejeune/docs/feasibility_assessment_Lejeune.pdf

Bove FJ, Ruckart PZ, Maslia M, Larson TC. Evaluation of mortality among marines and navy personnel exposed to contaminated drinking water at USMC base camp Lejeune: a retrospective cohort study. Environmental Health 2014a; 13:10.

Bove FJ, Ruckart PZ, Maslia M, Larson TC. Mortality study of civilian employees exposed to contaminated drinking water at USMC Base Camp Lejeune: a retrospective cohort study. Environmental Health 2014b; 13:68.

Cohn P, Klotz J, Bove F, Fagliano J. Drinking water contamination and the incidence of leukemia and non-Hodgkin's lymphoma. Environ Health Perspect 1994; 102:556-61.

Defense Manpower Data Center (DMDC). DMDC Profile: Information and Technology for Better Decision Making. Department of Defense, Arlington VA and Seaside CA, 2004.

Dillman DA. Mail and Internet surveys: The tailored design method (2nd ed., 2007 update). Hoboken, NJ: John Wiley & Sons, 2007.

Environmental Protection Agency (EPA). Final health assessment for TCE. 2011. Washington, DC [accessed 2017 August 3]. Available from: http://www.epa.gov/IRIS/subst/0199.htm.

Environmental Protection Agency (EPA). Toxicological review of tetrachloroethylene (perchloroethylene). 2012. Washington, DC [accessed 2017 August 3]. Available from: http://www.epa.gov/iris/toxreviews/0106tr.pdf

Gash DM, Rutland K, Hudson NL, Sullivan PG, Bing G, Cass WA, Pandya JD, Liu M, Choi DY, Hunter RL, Gerhardt GA, Smith CD, Slevin JT, Prince TS. Trichloroethylene: parkinsonism and complex 1 mitochondrial neurotoxicity. Ann Neurol 2008;63:184–192.

Goldman SM, Quinlan PJ, Ross GW, Marras C, Meng C, Bhudhikanok GS, Comyns K, Korell M, Chade AR, Kasten M, Priestley B, Chou KL, Fernandez HH, Cambi F, Langston JW, Tanner CM. Solvent exposures and Parkinson disease risk in twins. Ann Neurol 2012;71:776-784.

Hill, Austin Bradford (1965). The Environment and Disease: Association or Causation? Proceedings of the Royal Society of Medicine 1965l 58(5) 295–300.

Hirsch L, Jette N, Frolkis A, Steeves T, Pringsheim T. The incidence of Parkinson's disease: A systematic review and meta-analysis. Neuroepidemiology 2016;46:292-300.

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol 97: 1,3-Butadiene, Ethylene Oxide and Vinyl Halides (Vinyl Fluoride, Vinyl Chloride and Vinyl Bromide). Lyon, France 2008.

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol 100F. Chemical Agents and Related Occupations. A Review of Human Carcinogens. Lyon, France 2012.

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol 106. Trichloroethylene, Tetrachloroethylene, and Some Other Chlorinated Agents. Lyon, France 2014.

Institute of Medicine (IOM). Review of VA Clinical Guidance for the Health Conditions Identified by the Camp Lejeune Legislation. 2015.

Karami S, Lan Q, Rothman N, Stewart PA, Lee KM, Vermeulen R, Moore LE. Occupational trichloroethylene exposure and kidney cancer risk: a meta-analysis. Occup Environ Med 2012;69:858–867.

Karami S, Bassig B, Stewart PA, Lee KM, Moore LE, Lan Q. Occupational trichloroethylene exposure and risk of lymphatic and hematopoietic cancers: a meta-analysis Occup Environ Med 2013; 70:591-9.

Kriebel D, Zeka A, Eisen EA, Wegman DH. Quantitative evaluation of the effects of uncontrolled confounding by alcohol and tobacco in occupational cancer studies. In J Epidemiol2004;33:1040-1045.

Lock EA Zhang J, Checkoway H. Solvents and Parkinson disease: A systematic review of toxicological and epidemiological evidence. Toxicol Appl Pharmacol 2013;266:345-355.

Maldonado G, Greenland S. Simulation Study of Confounder-Selection Strategies Am. J. Epidemiol.1993; 138: 923 - 936.

Maslia ML, Sautner JB, Faye RE, Suarez-Soto RJ, Aral MM, Grayman WM, Jang W, Wang J, Bove FJ, Ruckart PZ, Valenzuela C, Green JW Jr, Krueger AL. Analyses of groundwater flow, contaminant fate and transport, and distribution of drinking water at Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical reconstruction and present-day conditions – Executive Summary. Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2007. http://www.atsdr.cdc.gov/sites/lejeune/tarawaterrace.html

Maslia ML, Suárez-Soto RJ, Sautner JB, Anderson BA, Jones LE, Faye RE, Aral MM, Guan J, Jang W, Telci IT, Grayman WM, Bove FJ, Ruckart PZ, Moore SM. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Summary and Resultss. Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2013. http://www.atsdr.cdc.gov/sites/lejeune/hadnotpoint.html

Monson RR. Occupational Epidemiology, 2nd Edition. CRC Press (Boca Raton, FL 1990), pages 88-89.

National Toxicology Program (NTP). Report on Carcinogens. Monograph on Trichloroethylene. January 2015. [accessed 2017 August 1]. Available from: https://ntp.niehs.nih.gov/ntp/roc/monographs/finaltce_508.pdf

National Toxicology Program (NTP). Report on carcinogens. 14th edition. Research Triangle Park, NC: US Department of Health and Human Services; 2016.

Paulu C, Aschengrau A, Ozonoff, D. Tetrachloroethylene-contaminated drinking water in Massachusetts and the risk of colon-rectum, lung, and other cancers. Environ Health Perspect 1999;107:265-71.

Porta M. ed. A Dictionary of Epidemiology, Sixth Edition, Edited for the International Epidemiological Association. Oxford University Press (2014, NY) pp. 200, 246.

Purdue MP, Stewart PA, Friesen MC, Colt JS, Locke SL, Hein MJ, Waters MA, Graubard BI, Davis F, Ruterbusch J, Schwartz K, Chow WH, Rothman N, Hofmann J. Occupational

exposure to chlorinated solvents and kidney cancer: a case–control study. Occup Environ Med 2017;74:268–274.

Rothman KJ, Greenland S, Lash TL: Modern Epidemiology. 3rd edition. Philadelphia, PA: Walters Kluwer/ Lippincott Williams & Wilkins; 2008.

Rothman KJ: Curbing type I and type II errors. Eur J Epidemiol 2010, 25:223–224.

Rothman KJ. Six persistent research misconceptions. J Gen Intern Med. 2014;29:1060-4.

Ruckart PZ, Bove FJ, Maslia M. Evaluation of exposure to contaminated drinking water and specific birth defects and childhood cancers at Marine Corps Base Camp Lejeune, North Carolina: a case-control study. Environmental Health 2013, 12:104 doi:10.1186/1476-069X-12-104.

Ryan MAK, Smith TC, Smith B, Amoroso P, Boyko EJ, Gray GC, Gackstetter GD, Riddler JR, Wells TS, Gumbs G, Corbeil TE, Hooper TI. Millennium Cohort: enrollment begins a 21-year contribution to understanding the impact of military service. J Clin Epidemiol 2007; 60:181-91.

SAS Institute Inc. 2011. SAS® software version 9.3.Cary, NC: SAS Institute Inc.

Scott CS and Jinot J. Trichloroethylene and Cancer: Systematic and Quantitative Review of Epidemiologic Evidence for Identifying Hazards. Int. J. Environ. Res. Public Health 2011; 8: 4238-4272.

Schrag A, Schott JM. Epidemiological, clinical and genetic characteristics of early-onset parkinsonism. Lancet Neurol 2006;5(4):355-363.

Stang A, Poole C, Kuss O. The ongoing tyranny of statistical significance testing in biomedical research. Eur J Epidemiol 2010, 25:225–30.

Stayner L, Steenland K, Dosemeci M, Hertz-Picciotto I: Attenuation of exposure-response curves in occupational cohort studies at high exposure levels. Scand J Work Environ Health 2003, 29:317-324.

van der Merwe C, Haylett W, Harvey J, Lombard D, Bardien S, Carr J. Factors influencing the development of early- or late-onset Parkinson's disease in a cohort of South African patients. S Afr Med J 2012;102(11):848-851.

Vieira V, Aschengrau A, Ozonoff D. Impact of tetrachloroethylene-contaminated drinking water on the risk of breast cancer: Using a dose model to assess exposure in a case-control study. Environ Health 2005, 4:3.

Vlaanderen J, Lan Q, Kromhout H, Rothman N, Vermeulen R. Occupational benzene

exposure and the risk of lymphoma subtypes: a meta-analysis of cohort studies incorporating three study quality dimensions. Environ Health Perspect 2011;119:159–167.

Vlaanderen J, Lan Q, Kromhout H, Rothman N, Vermeulen R. Occupational benzene exposure and the risk of chronic myeloid leukemia: a meta-analysis of cohort studies incorporating study quality dimensions. Am J Ind Med 2012;55:779-785.

Vlaanderen J, Straif K, Ruder A, Blair A, Hansen J, Lynge E, Charbotel B, Loomis D, Kauppinen T, Kyyronen P, Pukkala E, Weiderpass E, Guha N. Tetrachloroethylene exposure and bladder cancer risk: a meta-analysis of dry-cleaning worker studies. Environ Health Perspect 2014;122:661-666.

Zaheer F, Slevin JT. Trichloroethylene and Parkinson disease. Neurol Clin 2011;29:657-665.

**TABLES**

**Table 1. Participation in the health survey, by cohort type**

| | Camp Lejeune Marines | Camp Pendleton Marines | Camp Lejeune Civilian Employees | Camp Pendleton Civilian Employees | 1999-2002 ATSDR Survey Participant |
|---|---|---|---|---|---|
| Initial Sample | 214970 | 50000 | 8085 | 7236 | 29996 |
| Not locatable | 35617 (16.6%) | 8186 (16.4%) | 2632 (32.5%) | 2833 (39.2%) | 13225 (44.1%) |
| Not returned | 119581 (55.6%) | 28293 (56.7%) | 2681 (33.1%) | 2401 (33.2%) | 10255 (34.2%) |
| Refused | 5313 (2.5%) | 1836 (3.7%) | 286 (3.5%) | 340 (4.7%) | 454 (1.5%) |
| Deceased, no next of kin identified | 195 (<0.1%) | 53 (0.1%) | 13 (<0.1%) | 19 (<0.1%) | 35 (<0.1%) |
| Completed a survey | 54263 (25.2%) | 11632 (23.3%) | 2473 (30.6%) | 1662 (23.0%) | 6027 (20.1%) |
| Total complete after cohort corrections based on survey information* | 56251 | 9665 | 2466 | 1641 | N/A |
| Excluded from analyses because did not complete requested HIPAA form | 5567 | 1050 | 298 | 216 | 764 |
| Total for analyses of diseases | 50684 | 8615 | 2168 | 1425 | 5263 |

**Abbreviation:** HIPAA = Health Insurance Portability and Accountability Act.

*1 survey participant initially classified as a Camp Lejeune Marine was reclassified as a Camp Pendleton Marine; 1966 survey participants initially classified as Camp Pendleton Marines were reclassified as Camp Lejeune Marines; 11 survey participants initially classified as Camp Lejeune civilian employees and 10 survey participants initially classified as Camp Pendleton civilian employees were reclassified as Camp Lejeune Marines; 4 survey participants initially classified as Camp Pendleton civilian employees were reclassified as Camp Lejeune civilian employees; 7 survey participants who were initially classified as Camp Pendleton civilian employees were excluded because they married a Marine and then lived at Camp Lejeune.

**Table 2. TCE and PCE exposure categories used in the health survey, by type of analysis for both sexes combined***

| Analyses | Levels of cumulative exposure in ppb-months | |
|---|---|---|
| | **TCE** | **PCE** |
| **Camp Lejeune vs Camp Pendleton Marines**† | | |
| Low exposure (<50th percentile) | <110 | >0-<36 |
| Medium exposure (≥50th-<90th percentile) | ≥110-<11030 | ≥36-<711 |
| High exposure (≥90th percentile) | ≥11030 | ≥711 |
| **Camp Lejeune Marines internal analyses** | | |
| No/Low exposure (≤50th percentile) | <110 | >0-<36 |
| Medium exposure (>50th-≤90th percentile) | ≥110-<11030 | ≥36-<711 |
| High exposure (≥90th percentile) | ≥11030 | ≥711 |
| **Camp Lejeune vs Camp Pendleton civilian employees** | | |
| Low exposure (<50th percentile) | <10868 | <457 |
| Medium exposure (≥50th-<90th percentile) | ≥10868-<50563 | ≥457-<2118 |
| High exposure (≥90th percentile) | ≥50563 | ≥2118 |
| **Camp Lejeune civilian employees internal analyses** | | |
| No/Low exposure (≤50th percentile) | <10868 | <457 |
| Medium exposure (>50th-≤90th percentile) | ≥10868-<50563 | ≥457-<2118 |
| High exposure (≥90th percentile) | ≥50563 | ≥2118 |

Abbreviations: TCE = trichloroethylene and PCE = tetrachloroethylene.

*cut-points were similar for analysis of sex-specific diseases.

†For female Marines, cut points were chosen based on the 75th (3948 ppb-months for TCE and 167 ppb-months for PCE) and 90th (7863 ppb-months for TCE and 441 ppb-months for PCE) percentiles because the 50th percentile was 0 ppb for the contaminants.

**Table 3. Characteristics of Camp Lejeune Marines who completed a survey compared with Camp Pendleton Marines who completed a survey**

| Characteristic | Camp Lejeune (n=56251) | | Camp Pendleton (n=9665) | |
|---|---|---|---|---|
| | No. | % | No. | % |
| **Race** | | | | |
| White | 44809 | 79.7 | 8194 | 84.8 |
| Black | 10109 | 18.0 | 1059 | 11.0 |
| Other | 1281 | 2.3 | 393 | 4.1 |
| Missing | 52 | 0.1 | 19 | 0.2 |
| **Sex** | | | | |
| Male | 52957 | 94.1 | 7720 | 79.9 |
| Female | 3294 | 5.9 | 1945 | 20.1 |
| **Education** | | | | |
| High school graduate | 50335 | 89.5 | 8755 | 90.6 |
| Not a high school graduate | 5725 | 10.2 | 863 | 8.9 |
| Missing | 191 | 0.3 | 47 | 0.5 |
| **Rank** | | | | |
| Enlisted | 50101 | 89.1 | 8328 | 86.2 |
| Officer | 6140 | 10.9 | 1337 | 13.8 |
| Missing | 10 | <0.1 | 0 | 0.0 |
| **Served in Vietnam** | | | | |
| No service | 50681 | 90.1 | 8928 | 92.4 |
| Served < 1 year | 1307 | 2.3 | 194 | 2.0 |
| Served 1- <2 years | 2933 | 5.2 | 381 | 3.9 |
| Served ≥ 2 years | 1034 | 1.8 | 124 | 1.3 |
| Missing | 296 | 0.5 | 38 | 0.4 |
| **Age at survey or death** | | | | |
| < 50 years | 13812 | 24.6 | 2242 | 23.2 |
| 50-54 years | 18988 | 33.8 | 3351 | 34.7 |
| 55-59 years | 14720 | 26.2 | 2554 | 26.4 |
| 60-64 years | 4513 | 8.0 | 865 | 9.0 |
| ≥ 65 years | 4201 | 7.5 | 651 | 6.7 |
| Missing | 17 | <0.1 | 2 | <0.1 |
| **Worked with pesticides** | | | | |
| Yes | 10480 | 18.6 | 1783 | 18.5 |
| No | 41829 | 74.4 | 7218 | 74.7 |
| Missing | 3942 | 7.0 | 664 | 6.9 |
| **Worked with radiation** | | | | |
| Yes | 13357 | 23.8 | 2739 | 28.3 |
| No | 38594 | 68.6 | 6230 | 64.5 |
| Missing | 4300 | 7.6 | 696 | 7.2 |

| Characteristic | Camp Lejeune (n=56251) | | Camp Pendleton (n=9665) | |
|---|---|---|---|---|
| | No. | % | No. | % |
| **Worked with metals** | | | | |
| Yes | 9422 | 16.8 | 1789 | 18.5 |
| No | 42045 | 74.8 | 7080 | 73.3 |
| Missing | 4784 | 8.5 | 796 | 8.2 |
| **Worked with solvents** | | | | |
| Yes | 21899 | 38.9 | 3618 | 37.4 |
| No | 31035 | 55.2 | 5465 | 56.5 |
| Missing | 3317 | 5.9 | 582 | 6.0 |
| **Worked with other chemicals** | | | | |
| Yes | 14669 | 26.1 | 2341 | 24.2 |
| No | 37020 | 65.8 | 6564 | 67.9 |
| Missing | 4562 | 8.1 | 760 | 7.9 |
| **Ever smoked cigarettes** | | | | |
| Yes | 33923 | 60.3 | 5528 | 57.2 |
| No | 20608 | 36.6 | 3787 | 39.2 |
| Missing | 1720 | 3.1 | 350 | 3.6 |
| **Current number of alcoholic drinks** | | | | |
| Not a current drinker | 18703 | 33.3 | 2893 | 29.9 |
| <1 drink per month | 7134 | 12.7 | 1386 | 14.3 |
| 1-3 drinks per month | 7704 | 13.7 | 1369 | 14.2 |
| 1-4 drinks per week | 14194 | 25.2 | 2480 | 25.7 |
| Drinks daily or almost daily | 4956 | 8.8 | 892 | 9.2 |
| Missing | 3560 | 6.3 | 645 | 6.7 |

**Table 4. Characteristics of Camp Lejeune workers who completed a survey compared with Camp Pendleton workers who completed a survey**

| Characteristic | Camp Lejeune (n=2466) | | Camp Pendleton (n=1641) | |
|---|---|---|---|---|
| | No. | % | No. | % |
| **Race** | | | | |
| White | 1987 | 80.6 | 1332 | 81.2 |
| Black | 373 | 15.1 | 120 | 7.3 |
| Other | 106 | 4.3 | 189 | 11.5 |
| **Sex** | | | | |
| Male | 1001 | 40.6 | 771 | 47.0 |
| Female | 1465 | 59.4 | 870 | 53.2 |
| **Education** | | | | |
| High school graduate | 1784 | 72.3 | 1215 | 74.0 |
| Not a high school graduate | 168 | 6.8 | 87 | 5.3 |
| Missing | 514 | 20.8 | 339 | 20.7 |
| **Age at survey or death** | | | | |
| < 50 years | 46 | 1.9 | 28 | 1.7 |
| 50-54 years | 169 | 6.9 | 130 | 7.9 |
| 55-59 years | 451 | 18.3 | 293 | 17.9 |
| 60-64 years | 596 | 24.2 | 318 | 19.4 |
| ≥ 65 years | 1204 | 48.8 | 872 | 53.1 |
| **Blue collar worker** | | | | |
| Yes | 686 | 27.8 | 519 | 31.6 |
| No | 1772 | 71.9 | 1115 | 67.9 |
| Missing | 8 | 0.3 | 7 | 0.4 |
| **Worked with PAHs** | | | | |
| Yes | 3 | 0.1 | 9 | 0.5 |
| No | 2455 | 99.6 | 1624 | 99.0 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Worked as a painter** | | | | |
| Yes | 26 | 1.1 | 15 | 0.9 |
| No | 2432 | 98.6 | 1618 | 98.6 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Worked as cook/in food prep** | | | | |
| Yes | 22 | 0.9 | 25 | 1.5 |
| No | 2436 | 98.8 | 1608 | 98.0 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Worked with solvents** | | | | |
| Yes | 553 | 22.4 | 436 | 26.6 |
| No | 1905 | 77.3 | 1197 | 72.9 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Worked in the laundry** | | | | |
| Yes | 33 | 1.3 | 21 | 1.3 |

| Characteristic | Camp Lejeune (n=2466) | | Camp Pendleton (n=1641) | |
|---|---|---|---|---|
| | No. | % | No. | % |
| No | 2425 | 98.3 | 1612 | 98.2 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Worked with pesticides** | | | | |
| Yes | 30 | 1.2 | 7 | 0.4 |
| No | 2428 | 98.5 | 1626 | 99.1 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Worked with radiation** | | | | |
| Yes | 22 | 0.9 | 25 | 1.5 |
| No | 2436 | 98.8 | 1608 | 98.0 |
| Missing | 8 | 0.3 | 8 | 0.5 |
| **Ever smoked cigarettes** | | | | |
| Yes | 1226 | 49.7 | 906 | 55.2 |
| No | 1157 | 46.9 | 679 | 41.4 |
| Missing | 83 | 3.4 | 56 | 3.4 |
| **Current number of alcoholic drinks** | | | | |
| Not a current drinker | 926 | 37.6 | 638 | 38.9 |
| <1 drink per month | 317 | 12.9 | 221 | 13.5 |
| 1-3 drinks per month | 241 | 9.8 | 192 | 11.7 |
| 1-4 drinks per week | 392 | 15.9 | 257 | 15.7 |
| Drinks daily or almost daily | 152 | 6.2 | 143 | 8.7 |
| Missing | 438 | 17.8 | 190 | 11.6 |

**Abbreviation**: polycyclic aromatic hydrocarbons.

**Table 5. Summary of odds ratios and confidence intervals for all analyses conducted in Marines and civilian workers**

| Outcome | Marines | | | | | Civilian workers | | |
|---|---|---|---|---|---|---|---|---|
| | | TCE | | PCE | | | TCE/PCE | |
| | CL vs CP | CL vs CP high exposure | Internal analyses high exposure | CL vs CP high exposure | Internal analyses high exposure | CL vs CP | CL vs CP high exposure | Internal analyses high exposure |
| *Cancers*:* | | | | | | | | |
| **Digestive organs** | | | | | | | | |
| Colon | 1.4 (0.9, 2.0) | 1.1 (0.6, 2.0) | 0.9 (0.5, 1.5) | 1.9 (1.2, 3.2) | 1.5 (1.0, 2.2) | 1.5 (0.8, 3.0) | 4.7* (1.8, 12.7) | 5.5* (1.9, 16.1) |
| Esophageal | 1.5 (0.6, 3.5) | 2.7* (0.9, 8.2) | 1.2 (0.5, 2.9) | 2.9 (1.0, 8.4) | 1.6 (0.7, 3.5) | 0.9 (0.2, 4.0) | -- | -- |
| Liver | 0.9 (0.5, 1.9) | 0.7 (0.2, 2.2) | 1.2 (0.4, 3.5) | 0.7 (0.2, 2.2) | 1.3 (0.4, 3.8) | 0.3 (0.1, 1.6) | -- | -- |
| Pancreatic | 2.3 (0.9, 5.6) | 0.7 (0.1, 3.4) | 0.3 (0.1, 1.2) | 2.7 (0.9, 8.0) | 1.4 (0.7, 2.8) | 0.8 (0.3, 2.2) | 2.8 (0.7, 11.1) | 12.5* (1.7, 90.5) |
| Rectal | 2.0 (0.8, 5.0) | 2.1 (0.7, 3.4) | 1.4 (0.6, 3.4) | 2.4* (0.8, 7.5) | 1.4* (0.6, 3.2) | 1.4 (0.4, 5.7) | 6.6 (1.3, 33.0) | 7.1 (1.2, 42.9) |
| **Hematopoietic** | | | | | | | | |
| Leukemia | 1.0 (0.6, 1.5) | 0.3 (0.1, 0.8) | 0.3 (0.1, 0.7) | 1.0 (0.5, 2.0) | 1.0 (0.5, 1.8) | 1.1 (0.4, 3.4) | 1.3 (0.2, 11.4) | 1.6 (0.2, 15.3) |
| Lymphomas | 1.1 (0.8, 1.5) | 0.9 (0.5, 1.5) | 0.9 (0.6, 1.5) | 1.0 (0.8, 10.5) | 1.1 (0.7, 1.8) | 1.3 (0.6, 2.8) | 1.7 (0.5, 6.4) | 1.9* (0.4, 8.1) |
| Multiple myeloma | 2.1 (0.7, 5.7) | 1.1 (0.2, 6.2) | 0.5 (0.1, 2.4) | 2.9* (0.6, 7.2) | 1.4* (0.5, 3.4) | 1.6 (0.3, 8.6) | 3.3 (0.3, 36.7) | 2.7 (0.2, 43.8) |
| **Respiratory system** | | | | | | | | |
| Larynx | 2.3 (0.7, 7.4) | 2.1 (0.5, 9.8) | 1.6 (0.5, 5.1) | 4.0* (1.1, 15.3) | 3.3* (1.4, 7.7) | 1.4 (0.1, 15.7) | -- | -- |
| Lung | 1.4 (1.0, 2.0) | 0.9 (0.5, 1.6) | 0.7 (0.4, 1.2) | 1.6 (1.0, 2.6) | 1.2 (0.8, 1.8) | 1.6 (0.9, 2.8) | 1.5 (0.6, 4.1) | 1.1 (0.4, 3.2) |
| **Sex-specific** | | | | | | | | |
| Breast (male) | -- | -- | 1.0 (0.1, 8.6) | -- | 1.3 (0.1, 11.3) | 0.8 (0.1, 12.6) | -- | -- |

| Outcome | Marines | | | | | Workers | | |
|---|---|---|---|---|---|---|---|---|
| | | TCE | | PCE | | | TCE/PCE | |
| | CL vs CP | CL vs CP high exposure | Internal analyses high exposure | CL vs CP high exposure | Internal analyses high exposure | CL vs CP | CL vs CP high exposure | Internal analyses high exposure |
| Breast (female) | 1.1 (0.8, 1.5) | 1.0 (0.7, 2.9) | 1.3 (0.6, 2.6) | 1.6 (0.8, 3.4) | 1.5 (0.7, 3.1) | 2.1 (1.3, 3.3) | 5.1* (2.4, 11.0) | 5.1* (2.3, 11.1) |
| Cervical | 2.0 (0.7, 6.0) | 3.3 (0.6, 18.4) | 1.1 (0.2, 4.9) | 1.6 (0.2, 15.0) | 0.5 (0.1, 4.2) | 0.2 (0.0, 1.3) | -- | -- |
| Prostate | 1.2 (1.0, 1.5) | 0.8 (0.6, 1.2) | 0.7 (0.5, 1.0) | 1.6 (1.2, 2.2) | 1.4 (1.1, 1.8) | 1.3 (0.9, 1.9) | 2.4 (1.4, 4.0) | 2.4* (1.3, 4.4) |
| **Urinary system** | | | | | | | | |
| Bladder | 1.6 (1.0, 2.6) | 0.9 (0.4, 2.0) | 0.7 (0.4, 1.4) | 2.1* (1.1, 3.8) | 1.5 (1.0, 2.4) | 0.8 (0.4, 1.8) | 1.8 (0.5, 6.5) | 1.8 (0.5, 6.8) |
| Kidney | 1.3 (0.9, 2.0) | 1.4 (0.8, 2.6) | 1.6* (1.0, 2.5) | 1.8 (1.0, 3.1) | 2.0* (1.3, 3.1) | 1.5 (0.7, 3.4) | 13.9 (5.1, 38.1) | 41.5* (10.2, 169.2) |
| **Other** | | | | | | | | |
| Brain | 1.1 (0.6, 1.9) | 0.9 (0.4, 2.1) | 0.9 (0.4, 1.9) | 1.3 (0.6, 3.1) | 1.5* (0.7, 2.9) | 4.0 (0.5, 33.4) | -- | -- |
| Pharynx | 1.3 (0.6, 2.7) | 1.3 (0.5, 3.7) | 1.6 (0.7, 3.7) | 0.8 (0.2, 2.5) | 0.7 (0.2, 2.1) | -- | -- | -- |
| Soft tissue | 1.3 (0.5, 3.0) | 1.3 (0.4, 4.2) | 1.4* (0.6, 3.6) | 1.9 (0.6, 5.6) | 2.2* (0.9, 5.0) | -- | -- | -- |
| *Other diseases:* | | | | | | | | |
| **Autoimmune** | | | | | | | | |
| Lupus | 1.5 (0.8, 2.8) | 1.5 (0.5, 4.0) | 0.9 (0.4, 2.2) | 1.5 (0.5, 4.2) | 1.0 | 2.4 (0.5, 11.8) | 3.3 (0.3, 36.7) | 4.7 (0.3, 76.1) |
| Scleroderma | 0.4 (0.2, 0.9) | 0.5 (0.1, 4.1) | 0.8 (0.1, 6.9) | 0.5 (0.1, 4.3) | 0.8 | 1.4 (0.1, 15.4) | -- | -- |
| **Nervous system** | | | | | | | | |
| Amyotrophic lateral sclerosis (ALS) | 0.8 (0.4, 1.7) | 1.1 (0.4, 3.3) | 1.7 (0.7, 4.3) | 1.9 (0.7, 4.9) | 2.6 (1.2, 5.7) | -- | -- | -- |

| Outcome | Marines | | | | | Workers | | |
|---|---|---|---|---|---|---|---|---|
| | | TCE | | PCE | | | TCE/PCE | |
| | CL vs CP | CL vs CP high exposure | Internal analyses high exposure | CL vs CP high exposure | Internal analyses high exposure | CL vs CP | CL vs CP high exposure | Internal analyses high exposure |
| Multiple sclerosis | 1.2 (0.7, 1.9) | 1.7* (0.9, 3.4) | 1.5* (0.8, 2.6) | 0.6 (0.3, 1.6) | 0.5 (0.4, 2.4) | 4.9 (0.6, 39.8) | 6.6* (0.4, 106.3) | 1.6* (0.2, 15.3) |
| Parkinson disease | 0.9 (0.5, 1.6) | 0.3 (0.1, 1.0) | 0.3 (0.1, 1.1) | 1.2 (0.6, 2.6) | 1.3 (0.7, 2.5) | 3.1 (1.2, 8.3) | 2.9* (0.7, 12.1) | 2.0* (0.5, 7.9) |
| **Male reproductive organs** | | | | | | | | |
| Infertility | 2.7 (1.3, 5.9) | 2.3 (0.9, 6.1) | 0.9 (0.5, 1.7) | 2.3 (0.9, 6.1) | 0.7 (0.4, 1.4) | -- | -- | -- |
| **Female reproductive organs** | | | | | | | | |
| Endometriosis | 1.3 (0.9, 1.9) | 1.8 (0.9, 3.9) | 1.3 (0.6, 2.7) | 1.7 (0.8, 3.7) | 1.3 (0.6, 2.7) | 1.8 (0.9, 3.8) | 0.6 (0.1, 4.8) | 0.4 (0.1, 2.9) |
| Infertility | 1.4 (1.0, 2.0) | 1.7 (0.8, 3.6) | 1.1 (0.5, 2.2) | 1.6 (0.8, 3.4) | 1.1 (0.5, 2.2) | 2.1 (1.0, 4.2) | 0.6 (0.1, 4.8) | 0.3 (0.0, 2.4) |
| **Other** | | | | | | | | |
| Aplastic anemia | 0.8 (0.3, 2.1) | 0.3 (0.0, 2.8) | 0.5 (0.1, 3.5) | 1.3 (0.3, 4.9) | 1.7* (0.5, 5.6) | -- | -- | -- |
| Kidney disease | 1.7 (1.1, 2.5) | 1.4 (0.8, 2.5) | 1.0 (0.7, 1.6) | 2.0* (1.2, 3.4) | 1.5* (1.0, 2.3) | 1.2 (0.5, 2.6) | 2.7 (0.8, 8.5) | 4.7* (1.2, 19.1) |
| Liver disease | 1.4 (1.1, 1.9) | 1.4 (0.9, 2.1) | 1.2 (0.8, 1.6) | 1.6* (1.0, 2.4) | 1.3* (0.9, 1.8) | 1.1 (0.5, 2.3) | 0.6 (0.1, 4.7) | 0.5 (0.1, 3.7) |
| TCE-related skin disorder | -- | -- | -- | -- | -- | -- | -- | -- |

**Abbreviations:** CL = Camp Lejeune, CP = Camp Pendleton (referent).

-- could not be calculated because of zero cells.

* = Positive monotonic exposure-response relationship.

**Table 6. Odds ratios comparing cancers and other disease among Camp Lejeune Marines with those of Camp Pendleton Marines (referent)**

| Outcome | Camp Lejeune cases No., % | Camp Pendleton cases No., % | OR (95% CI) |
|---|---|---|---|
| *Cancers*:* | | | |
| **Digestive organs** | | | |
| Colon | 246, 0.52 | 31, 0.39 | 1.36 (0.93, 1.97) |
| Esophageal† | 52, 0.11 | 6, 0.08 | 1.48 (0.64, 3.46) |
| Liver | 49, 0.10 | 9, 0.11 | 0.93 (0.46, 1.89) |
| Pancreatic | 66, 0.14 | 5, 0.06 | 2.26 (0.91, 5.62) |
| Rectal | 59, 0.13 | 5, 0.06 | 2.01 (0.81, 5.01) |
| **Hematopoietic** | | | |
| Leukemia | 125, 0.27 | 22, 0.27 | 0.97 (0.61, 1.52) |
| Lymphomas | 232, 0.49 | 37, 0.46 | 1.06 (0.75, 1.50) |
| Multiple myeloma† | 48, 0.10 | 4, 0.05 | 2.06 (0.74, 5.71) |
| **Respiratory system** | | | |
| Laryngeal | 40, 0.09 | 3, 0.04 | 2.28 (0.71, 7.38) |
| Lung | 299, 0.64 | 36, 0.45 | 1.43 (1.01, 2.02) |
| **Sex-specific** | | | |
| Breast (male) | 12, 0.03 | 0 | -- |
| Breast (female) | 109, 4.56 | 53, 3.74 | 1.05 (0.75, 1.47) |
| Cervical | 18, 0.78 | 4, 0.29 | 2.01 (0.68, 6.00) |
| Prostate | 903, 1.99 | 110, 1.63 | 1.23 (1.01, 1.50) |
| **Urinary system** | | | |
| Bladder | 182, 0.39 | 19, 0.24 | 1.64 (1.02, 2.64) |
| Kidney | 192, 0.41 | 25, 0.31 | 1.31 (0.86, 1.99) |
| **Other** | | | |
| Brain | 90, 0.19 | 14, 0.18 | 1.07 (0.61, 1.89) |
| Pharyngeal | 61, 0.13 | 8, 0.10 | 1.29 (0.62, 2.70) |
| Soft tissue | 45, 0.10 | 6, 0.08 | 1.27 (0.54, 2.97) |
| *Other diseases:* | | | |
| **Autoimmune** | | | |
| Lupus‡ | 69, 0.15 | 12, 0.15 | 1.50 (0.80, 2.83) |
| Scleroderma | 15, 0.03 | 7, 0.09 | 0.37 (0.15, 0.90) |
| **Nervous system** | | | |
| Amyotrophic lateral sclerosis (ALS) | 38, 0.08 | 8, 0.10 | 0.81 (0.38, 1.74) |
| Multiple sclerosis‡ | 117, 0.25 | 22, 0.27 | 1.19 (0.74, 1.90) |
| Parkinson disease | 78, 0.17 | 15, 0.19 | 0.89 (0.51, 1.55) |
| **Male reproductive organs** | | | |
| Infertility | 129, 0.29 | 7, 0.11 | 2.74 (1.28, 5.87) |
| *Abnormal sperm* | 33, 0.07 | 2, 0.03 | 2.46 (0.59, 10.24) |

| Outcome | Camp Lejeune cases No., % | Camp Pendleton cases No., % | OR (95% CI) |
|---|---|---|---|
| *Epididymitis* | 4, 0.01 | 0 | -- |
| *Low sperm count* | 55, 0.12 | 2, 0.03 | 4.10 (1.00, 16.81) |
| *Low testosterone* | 36, 0.08 | 5, 0.08 | 1.07 (0.42, 2.74) |
| **Female reproductive organs** | | | |
| Endometriosis | 84, 3.55 | 39, 2.78 | 1.29 (0.88, 1.89) |
| Infertility | 105, 4.40 | 45, 3.20 | 1.39 (0.98, 1.99) |
| *Amenorrhea* | 2, 0.09 | 1, 0.07 | 1.20 (0.11, 13.19) |
| *Fallopian tube damage* | 8, 0.35 | 1, 0.07 | 4.78 (0.60, 38.26) |
| *Ovulation disorder* | 6, 0.26 | 1, 0.07 | 3.59 (0.43, 29.81) |
| **Other** | | | |
| Aplastic anemia | 23, 0.05 | 5, 0.06 | 0.79 (0.30, 2.07) |
| Kidney disease | 268, 0.57 | 27, 0.34 | 1.70 (1.14, 2.52) |
| *End stage renal‡* | 88, 0.19 | 8, 0.10 | 1.68 (0.81, 3.47) |
| *Glomerulonephritis* | 38, 0.08 | 7, 0.09 | 0.93 (0.41, 2.08) |
| *Goodpastures syndrome* | 0 | 0 | -- |
| *Nephrotic syndrome†* | 63, 0.13 | 5, 0.06 | 2.15 (0.87, 5.36) |
| *Renal failure* | 136, 0.29 | 14, 0.17 | 1.66 (0.96, 2.88) |
| *Renal sclerosis†* | 17, 0.04 | 2, 0.03 | 1.45 (0.34, 6.29) |
| Liver disease | 456, 0.97 | 55, 0.68 | 1.42 (1.07, 1.88) |
| *Biliary cirrhosis†* | 2, 0.00 | 1, 0.01 | 0.34 (0.03, 3.77) |
| *Cirrhosis†* | 77, 0.16 | 9, 0.11 | 1.46 (0.73, 2.92) |
| *Fatty liver* | 359, 0.76 | 40, 0.50 | 1.53 (1.11, 2.13) |
| *Hepatomegaly* | 39, 0.08 | 7, 0.09 | 0.95 (0.43, 2.13) |
| *Liver failure†* | 22, 0.05 | 2, 0.03 | 1.88 (0.44, 8.00) |
| *Necrosis* | 5, 0.01 | 0 | -- |
| TCE-related skin disorder | 9, 0.02 | 0 | -- |

**Abbreviations:** OR = odds ratio; CI = confidence interval; TCE = trichloroethylene.

* All causes of cancer adjusted for age at diagnosis.

† These conditions were reported only in men. ORs for men only were: esophageal cancer 1.29 (0.56, 3.01); myeloma 1.79 (0.65, 4.97); biliary cirrhosis 0.30 (0.03, 3.29); cirrhosis 1.28 (0.64, 2.55); liver failure 1.65 (0.39, 7.00); nephrotic syndrome 1.88 (0.76, 4.67); renal sclerosis 1.27 (0.29, 5.48).

‡Adjusted for sex.

**Table 7. Odds ratios for cumulative TCE exposure in Marines at Camp Lejeune compared with those at Camp Pendleton (referent)**

| Outcome | Low exposure | | Medium exposure | | High exposure | |
|---|---|---|---|---|---|---|
| | No. | OR (95% CI) | No. | OR (95% CI) | No. | OR (95% CI) |
| *Cancers*, †:* | | | | | | |
| **Digestive organs** | | | | | | |
| Colon (n=277) | 133 | 1.25 (0.82, 1.89) | 92 | 1.20 (0.78, 1.85) | 21 | 1.11 (0.62, 2.00) |
| Esophageal‡ (n=58) | 25 | 1.74 (0.71, 4.27) | 20 | 1.81 (0.72, 4.54) | 7 | 2.71 (0.89, 8.20) |
| Liver (n=58) | 17 | 0.61 (0.27, 1.39) | 28 | 1.22 (0.57, 2.64) | 4 | 0.65 (0.20, 2.16) |
| Pancreatic (n=71) | 36 | 1.89 (0.73, 4.90) | 28 | 2.10 (0.80, 5.53) | 2 | 0.65 (0.12, 3.41) |
| Rectal (n=64) | 25 | 1.46 (0.55, 3.89) | 27 | 2.15 (0.82, 5.68) | 7 | 2.12 (0.65, 6.85) |
| **Hematopoietic** | | | | | | |
| Leukemia (n=147) | 80 | 1.08 (0.66, 1.78) | 41 | 0.76 (0.44, 1.30) | 4 | 0.28 (0.09, 0.83) |
| Lymphomas (n=269) | 114 | 0.89 (0.60, 1.33) | 97 | 1.06 (0.70, 1.60) | 21 | 0.85 (0.48, 1.51) |
| Multiple myeloma‡ (n=52) | 19 | 1.86 (0.63, 5.52) | 27 | 3.72 (1.29, 10.71) | 2 | 1.12 (0.20, 6.20) |
| **Respiratory system** | | | | | | |
| Laryngeal (n=43) | 15 | 1.32 (0.38, 4.64) | 21 | 2.79 (0.82, 9.50) | 4 | 2.12 (0.46, 9.75) |
| Lung (n=335) | 155 | 1.24 (0.84, 1.83) | 125 | 1.37 (0.92, 2.04) | 19 | 0.88 (0.49, 1.59) |
| **Sex-specific** | | | | | | |
| Breast (female) (n=162) | 83 | 1.10 (0.72, 1.66) | 12 | 1.01 (0.48, 2.11) | 14 | 1.40 (0.67, 2.91) |
| Cervical (n=22) | 14 | 3.07 (1.00, 9.46) | 2 | 2.21 (0.39, 12.40) | 2 | 3.25 (0.57, 18.43) |
| Prostate (n=1013) | 463 | 1.15 (0.90, 1.48) | 391 | 1.37 (1.06, 1.77) | 49 | 0.83 (0.56, 1.22) |
| **Urinary system** | | | | | | |
| Bladder (n=201) | 88 | 1.28 (0.76, 2.15) | 83 | 1.68 (1.00, 2.82) | 11 | 0.93 (0.43, 2.01) |
| Kidney (n=217) | 82 | 0.90 (0.56, 1.45) | 86 | 1.33 (0.84, 2.13) | 24 | 1.42 (0.78, 2.58) |
| **Other** | | | | | | |
| Brain (n=104) | 47 | 0.97 (0.52, 1.81) | 34 | 1.02 (0.53, 1.96) | 9 | 0.87 (0.36, 2.08) |
| Pharyngeal (n=69) | 22 | 0.86 (0.37, 1.96) | 31 | 1.54 (0.69, 3.40) | 8 | 1.34 (0.49, 3.65) |
| Soft tissue (n=51) | 21 | 0.94 (0.37, 2.38) | 18 | 1.18 (0.46, 3.01) | 6 | 1.33 (0.42, 4.23) |
| *Other diseases†:* | | | | | | |
| **Autoimmune** | | | | | | |
| Lupus (n=81) | 36 | 1.60 (0.81, 3.16) | 27 | 1.54 (0.76, 3.15) | 6 | 1.46 (0.53, 4.04) |
| Scleroderma (n=22) | 6 | 0.50 (0.16, 1.55) | 8 | 0.87 (0.30, 2.55) | 1 | 0.47 (0.06, 4.07) |
| **Nervous system** | | | | | | |
| Amyotrophic lateral sclerosis (ALS) (n=46) | 18 | 0.74 (0.32, 1.73) | 14 | 0.70 (0.29, 1.70) | 6 | 1.13 (0.38, 3.34) |
| Multiple sclerosis (n=139) | 56 | 1.17 (0.70, 1.96) | 45 | 1.18 (0.69, 2.02) | 16 | 1.70 (0.86, 3.36) |
| Parkinson disease (n=93) | 41 | 0.86 (0.47, 1.59) | 34 | 0.87 (0.46, 1.62) | 3 | 0.29 (0.08, 1.00) |
| **Male reproductive organs** | | | | | | |
| Infertility (n=136) | 64 | 2.69 (1.22, 5.92) | 54 | 2.83 (1.28, 6.29) | 11 | 2.31 (0.88, 6.05) |
| *Abnormal sperm (n=35)* | 17 | 2.50 (0.57, 10.87) | 16 | 2.94 (0.67, 12.86) | 0 | , , |
| *Low sperm count (n=57)* | 29 | 4.26 (1.01, 17.96) | 25 | 4.59 (1.08, 19.50) | 1 | 0.74 (0.07, 8.15) |
| *Low testosterone (n=41)* | 17 | 1.00 (0.37, 2.73) | 15 | 1.10 (0.40, 3.06) | 4 | 1.18 (0.31, 4.43) |

| Outcome | Low exposure | | Medium exposure | | High exposure | |
|---|---|---|---|---|---|---|
| | No. | OR (95% CI) | No. | OR (95% CI) | No. | OR (95% CI) |
| **Female reproductive organs** | | | | | | |
| Endometriosis (n=123) | 63 | 1.42 (0.91, 2.20) | 10 | 1.13 (0.53, 2.42) | 11 | 1.83 (0.86, 3.92) |
| Infertility (n=150) | 81 | 1.58 (1.05, 2.37) | 12 | 1.18 (0.58, 2.39) | 12 | 1.73 (0.83, 3.60) |
| *Amenorrhea (n=3)* | 2 | 1.75 (0.16, 19.48) | 0 | -- | 0 | -- |
| *Fallopian tube damage (n=9)* | 7 | 6.14 (0.75, 50.29) | 1 | 4.42 (0.27, 71.87) | 0 | -- |
| *Ovulation disorder (n=7)* | 6 | 5.26 (0.63, 44.04) | 0 | -- | 0 | -- |
| **Other** | | | | | | |
| Aplastic anemia (n=28) | 11 | 0.76 (0.26, 2.24) | 11 | 0.93 (0.32, 2.75) | 1 | 0.32 (0.04, 2.82) |
| Kidney disease (n=295) | 115 | 1.39 (.90, 2.15) | 127 | 1.86 (1.20, 2.87) | 26 | 1.43 (0.81, 2.52) |
| *End stage renal (n=96)* | 38 | 1.47 (0.68, 3.20) | 42 | 1.96 (0.91, 4.23 | 8 | 1.40 (0.52, 3.79) |
| *Glomerulonephritis (n=45)* | 13 | 0.62 (0.24, 1.57) | 23 | 1.33 (0.56, 3.15) | 2 | 0.44 (0.09, 2.13) |
| *Nephrotic syndrome‡ (n=68)* | 31 | 2.68 (1.04, 6.94) | 25 | 2.71 (1.03, 7.11) | 7 | 3.03 (0.95, 9.62) |
| *Renal failure (n=150)* | 56 | 1.38 (0.75, 2.51) | 68 | 2.03 (1.12, 3.68) | 12 | 1.37 (0.62, 3.02) |
| *Renal sclerosis‡ (n=19)* | 7 | 1.52 (0.31, 7.32) | 9 | 2.44 (0.53, 11.32) | 1 | 1.08 (0.10, 11.98) |
| Liver disease (n=511) | 192 | 1.19 (0.86, 1.64) | 217 | 1.63 (1.18, 2.25) | 48 | 1.36 (0.89, 2.07) |
| *Biliary cirrhosis‡ (n=3)* | 1 | 0.43 (0.03, 6.94) | 1 | 0.54 (0.03, 8.68) | 0 | -- |
| *Cirrhosis‡ (n=86)* | 34 | 1.64 (0.78, 3.44) | 36 | 2.17 (1.04, 4.53) | 7 | 1.68 (0.62, 4.57) |
| *Fatty liver (n=399)* | 151 | 1.32 (0.91, 1.91) | 171 | 1.81 (1.25, 2.63) | 38 | 1.53 (0.95, 2.46) |
| *Hepatomegaly (n=46)* | 11 | 0.50 (0.19, 1.30) | 22 | 1.20 (0.51, 2.86) | 6 | 1.24 (0.41, 3.74) |
| *Liver failure‡ (n=24)* | 12 | 2.60 (0.58, 11.65) | 7 | 1.90 (0.39, 9.15) | 3 | 3.24 (0.54, 19.52) |

**Abbreviations:** TCE = trichloroethylene; OR = odds ratio; CI = confidence interval.

*All causes of cancer adjusted for age at diagnosis if >2 cases per cell.

†Adjusted for sex if not a sex-specific disease and the disease was reported in both sexes.

‡ Reported only in men. ORs for men only are esophageal cancer low OR = 1.26 (0.52, 3.11), medium OR = 1.17 (0.46, 2.95) and high OR = 1.55 (0.49, 4.90); myeloma low OR = 1.37 (0.46, 4.05), medium OR = 2.40 (0.83, 6.97) and high OR = 0.75 (0.14, 4.18); nephrotic syndrome low OR = 2.00 (0.78, 5.15), medium OR = 1.62 (0.61, 4.31) and high OR = 2.06 (0.64, 6.57); renal sclerosis low OR = 1.18 (0.25, 5.56), medium OR = 1.47 (0.31, 6.96) and high OR = 0.74 (0.07, 8.15); biliary cirrhosis low OR = 0.29 (0.02, 4.71) and medium OR = 0.37 (0.02, 5.89); cirrhosis low OR = 1.11 (0.53, 2.34), medium OR = 1.47 (0.70, 3.09) and high OR = 1.14 (0.42, 3.12); liver failure low OR = 1.76 (0.39, 7.92), medium OR = 1.29 (0.27, 6.22) and high OR = 2.20 (0.37, 13.30).

Note: the numbers in parentheses after the diseases are the total number of cases at both bases.

**Table 8. Odds ratios for cumulative PCE exposure in Marines at Camp Lejeune compared with those at Camp Pendleton (referent)**

| | Low exposure | | Medium exposure | | High exposure | |
|---|---|---|---|---|---|---|
| **Outcome** | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** |
| *Cancers*,†:* | | | | | | |
| **Digestive organs** | | | | | | |
| Colon (n=277) | 136 | 1.28 (0.84, 1.94) | 70 | 0.95 (0.61, 1.49) | 40 | 1.92 (1.16, 3.20) |
| Esophageal‡ (n=58) | 26 | 1.81 (0.74, 4.43) | 18 | 1.67 (0.66, 4.24) | 8 | 2.88 (0.98, 8.41) |
| Liver (n=58) | 16 | 0.57 (0.25, 1.32) | 29 | 1.26 (0.59, 2.72) | 4 | 0.66 (0.20, 2.18) |
| Pancreatic (n=71) | 38 | 1.98 (0.77, 5.12) | 18 | 1.45 (0.53, 3.98) | 10 | 2.67 (0.89, 7.98) |
| Rectal (n=64) | 28 | 1.64 (0.62, 4.32) | 23 | 1.85 (0.69, 4.95) | 8 | 2.38 (0.76, 7.45) |
| **Hematopoietic** | | | | | | |
| Leukemia (n=147) | 72 | 0.96 (0.58, 1.59) | 39 | 0.73 (0.42, 1.27) | 14 | 0.98 (0.48, 1.98) |
| Lymphomas (n=269) | 111 | 0.86 (0.57, 1.28) | 97 | 1.07 (0.71, 1.61) | 24 | 1.01 (0.82, 10.54) |
| Multiple myeloma‡ (n=52) | 22 | 2.13 (0.73, 6.25) | 20 | 2.91 (1.00, 8.58) | 6 | 2.93 (0.55, 7.19) |
| **Respiratory system** | | | | | | |
| Laryngeal (n=43) | 14 | 1.22 (0.34, 4.31) | 17 | 2.44 (0.70, 8.47) | 9 | 4.04 (1.06, 15.34) |
| Lung (n=335) | 165 | 1.30 (0.89, 1.92) | 92 | 1.09 (0.72, 1.64) | 42 | 1.62 (1.00, 2.62) |
| **Sex-specific** | | | | | | |
| Breast (female) (n=162) | 82 | 1.08 (0.72, 1.64) | 13 | 0.95 (0.46, 1.95) | 14 | 1.64 (0.78, 3.44) |
| Cervical (n=22) | 14 | 3.07 (1.00, 9.45) | 3 | 3.31 (0.72, 15.28) | 1 | 1.63 (0.18, 14.97) |
| Prostate (n=1013) | 474 | 1.18 (0.92, 1.51) | 295 | 1.14 (0.87, 1.48) | 134 | 1.62 (1.18, 2.23) |
| **Urinary system** | | | | | | |
| Bladder (n=201) | 93 | 1.33 (0.80, 2.24) | 59 | 1.30 (0.76, 2.23) | 30 | 2.07 (1.12, 3.82) |
| Kidney (n=217) | 80 | 0.88 (0.55, 1.41) | 80 | 1.28 (0.79, 2.05) | 32 | 1.79 (1.02, 3.12) |
| **Other** | | | | | | |
| Brain (n=104) | 43 | 0.87 (0.47, 1.64) | 36 | 1.04 (0.55, 1.98) | 11 | 1.33 (0.58, 3.05) |
| Pharyngeal (n=69) | 27 | 1.06 (0.47, 2.37) | 30 | 1.43 (0.64, 3.16) | 4 | 0.75 (0.22, 2.53) |
| Soft tissue (n=51) | 20 | 0.89 (0.35, 2.26) | 17 | 1.10 (0.43, 2.85) | 8 | 1.88 (0.63, 5.57) |
| *Other diseases†:* | | | | | | |
| **Autoimmune** | | | | | | |
| Lupus (n=81) | 34 | 1.51 (0.76, 2.99) | 29 | 1.66 (0.82, 3.37) | 6 | 1.50 (0.54, 4.18) |
| Scleroderma (n=22) | 6 | 0.49 (0.16, 1.53) | 8 | 0.87 (0.30, 2.56) | 1 | 0.49 (0.06, 4.28) |
| **Nervous system** | | | | | | |
| Amyotrophic lateral sclerosis (ALS) (n=46) | 18 | 0.75 (0.32, 1.75) | 10 | 0.50 (0.19, 1.29) | 10 | 1.86 (0.71, 4.85) |
| Multiple sclerosis (n=139) | 58 | 1.19 (0.71, 2.00) | 53 | 1.37 (0.81, 2.32) | 6 | 0.63 (0.25, 1.60) |
| Parkinson disease (n=93) | 44 | 0.94 (0.51, 1.71) | 21 | 0.54 (0.27, 1.05) | 13 | 1.22 (0.57, 2.61) |
| **Male reproductive organs** | | | | | | |
| Infertility (n=136) | 74 | 3.11 (1.42, 6.81) | 44 | 2.31 (1.03, 5.17) | 11 | 2.31 (0.88, 6.05) |
| *Abnormal sperm (n=35)* | 21 | 3.09 (0.72, 13.25) | 11 | 2.02 (0.45, 9.16) | 1 | 0.74 (0.07, 8.15) |
| *Low sperm count (n=57)* | 37 | 5.44 (1.30, 22.71) | 18 | 3.30 (0.76, 14.31) | 0 | -- |
| *Low testosterone (n=41)* | 20 | 1.18 (0.44, 3.16) | 12 | 0.88 (0.31, 2.52) | 4 | 1.18 (0.31, 4.43) |

| Outcome | Low exposure | | Medium exposure | | High exposure | |
|---|---|---|---|---|---|---|
| | No. | OR (95% CI) | No. | OR (95% CI) | No. | OR (95% CI) |
| **Female reproductive organs** | | | | | | |
| Endometriosis (n=123) | 59 | 1.33 (0.85, 2.07) | 15 | 1.70 (0.87, 3.32) | 10 | 1.67 (0.76, 3.65) |
| Infertility (female) (n=150) | 76 | 1.48 (0.98, 2.23) | 18 | 1.77 (0.95, 3.31) | 11 | 1.59 (0.75, 3.37) |
| *Amenorrhea (n=3)* | 2 | 1.75 (0.16, 19.48) | 0 | -- | 0 | -- |
| *Fallopian tube damage (n=9)* | 7 | 6.14 (0.75, 50.29) | 1 | 4.42 (0.27, 71.87) | 0 | -- |
| *Ovulation disorder (n=7)* | 5 | 4.39 (0.51, 37.82) | 0 | -- | 1 | 6.50 (0.40, 106.38) |
| **Other** | | | | | | |
| Aplastic anemia (n=28) | 10 | 0.70 (0.23, 2.10) | 9 | 0.77 (0.25, 2.35) | 4 | 1.28 (0.33, 4.94) |
| Kidney disease (n=295) | 109 | 1.33 (0.85, 2.06) | 122 | 1.79 (1.15, 2.77) | 37 | 2.00 (1.18, 3.39) |
| *End stage renal (n=96)* | 37 | 1.44 (0.67, 3.14) | 39 | 1.82 (0.84, 3.95) | 12 | 2.05 (0.82, 5.11) |
| *Glomerulonephritis (n=45)* | 11 | 0.53 (0.20, 1.38) | 23 | 1.33 (0.56, 3.16) | 4 | 0.86 (0.25, 3.00) |
| *Nephrotic syndrome‡ (n=68)* | 25 | 2.17 (0.83, 5.69) | 26 | 2.82 (1.08, 7.38) | 12 | 5.19 (1.81, 14.89) |
| *Renal failure (n=150)* | 53 | 1.31 (0.72, 2.41) | 62 | 1.86 (1.02, 3.39) | 21 | 2.36 (1.17, 4.77) |
| *Renal sclerosis‡ (n=19)* | 8 | 1.73 (0.37, 8.19) | 6 | 1.63 (0.33, 8.08) | 3 | 3.24 (0.54, 19.54) |
| Liver disease (n=511) | 196 | 1.22 (0.88, 1.68) | 205 | 1.54 (1.11, 2.13) | 56 | 1.56 (1.03, 2.35) |
| *Biliary cirrhosis‡ (n=3)* | 2 | 0.87 (0.08, 9.57) | 0 | -- | 0 | -- |
| *Cirrhosis‡ (n=86)* | 31 | 1.49 (0.71, 3.16) | 36 | 2.17 (1.04, 4.53) | 10 | 2.40 (0.96, 5.99) |
| *Fatty liver (n=399)* | 155 | 1.36 (0.94, 1.97) | 158 | 1.68 (1.15, 2.44) | 47 | 1.86 (1.17, 2.94) |
| *Hepatomegaly (n=46)* | 15 | 0.68 (0.28, 1.70) | 18 | 0.98 (0.41, 2.39) | 6 | 1.21 (0.40, 3.66) |
| *Liver failure‡ (n=24)* | 13 | 2.82 (0.63, 12.52) | 9 | 2.44 (0.53, 11.32) | 0 | -- |

**Abbreviations:** PCE = tetrachloroethylene; OR = odds ratio; CI = confidence interval.

* All causes of cancer adjusted for age at diagnosis if >2 cases per cell.

†Adjusted for sex if not a sex, specific disease and the disease was reported in both sexes.

‡Reported only in men. ORs for men only are esophageal cancer low OR = 1.22 (0.50, 3.01), medium OR = 1.12 (0.44, 2.86), high OR = 1.94 (0.66, 5.70); myeloma low OR = 1.44 (0.49, 4.25), medium OR = 1.97 (0.67, 5.83) and high OR = 1.99 (0.55, 7.19); nephrotic syndrome low OR = 1.47 (0.56, 3.87), medium OR = 1.91 (0.73, 5.01) and high OR = 2.21 (0.37, 13.31); renal sclerosis low OR = 1.18 (0.25, 5.57), medium OR = 1.10 (0.22, 5.48) and high OR = 2.21 (0.37, 13.31); biliary cirrhosis low OR = 0.59 (0.05, 6.51); cirrhosis low OR = 1.11 (0.53, 2.34), medium OR = 1.39 (0.66, 2.92) and high OR = 1.47 (0.57, 3.76); liver failure low OR = 1.91 (0.43, 8.52), medium OR = 1.65 (0.36, 7.68).

**Table 9. Odds ratios for internal analyses of cumulative exposure to TCE among Camp Lejeune Marines**

| Outcome | Medium exposure | | High exposure | |
|---|---|---|---|---|
| | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** |
| *Cancers*:* | | | | |
| **Digestive organs** | | | | |
| Colon (n=246) | 92 | 0.97 (0.73, 1.28) | 21 | 0.89 (0.54, 1.46) |
| Esophageal †,‡ (n=52) | 19 | 0.90 (0.49, 1.65) | 6 | 1.18 (0.47, 2.94) |
| Liver† (n=49) | 28 | 2.05 (1.11, 3.79) | 4 | 1.17 (0.38, 3.54) |
| Pancreatic†,§ (n=66) | 28 | 0.98 (0.59, 1.61) | 2 | 0.28 (0.07, 1.16) |
| Rectal (n=59) | 27 | 1.45 (0.83, 2.54) | 7 | 1.44 (0.61, 3.44) |
| **Hematopoietic** | | | | |
| Leukemia (n=125) | 41 | 0.70 (0.47, 1.03) | 4 | 0.26 (0.09, 0.72) |
| Lymphomas (n=232) | 97 | 1.16 (0.87, 1.56) | 21 | 0.91 (0.55, 1.50) |
| Multiple myeloma‡,† (n=48) | 25 | 1.73 (0.95, 3.15) | 2 | 0.54 (0.12, 2.39) |
| **Respiratory system** | | | | |
| Laryngeal (n=40) | 21 | 2.09 (1.06, 4.12) | 4 | 1.62 (0.52, 5.10) |
| Lung (n=299) | 125 | 1.10 (0.85, 1.43) | 19 | 0.72 (0.43, 1.19) |
| **Sex-specific** | | | | |
| Breast (male)‖ (n=12) | 6 | 1.50 (0.46, 4.94) | 1 | 1.00 (0.12, 8.60) |
| Breast (female) (n=109) | 12 | 0.89 (0.44, 1.83) | 14 | 1.27 (0.62, 2.59) |
| Cervical‖ (n=18) | 2 | 0.72 (0.16, 3.27) | 2 | 1.06 (0.23, 4.86) |
| Prostate (n=903) | 391 | 1.18 (0.99, 1.39) | 49 | 0.70 (0.50, 0.98) |
| **Urinary system** | | | | |
| Bladder (n=182) | 83 | 1.34 (0.98, 1.85) | 11 | 0.74 (0.39, 1.43) |
| Kidney (n=192) | 86 | 1.45 (1.05, 2.00) | 24 | 1.55 (0.95, 2.54) |
| **Other** | | | | |
| Brain (n=90) | 34 | 1.04 (0.66, 1.65) | 9 | 0.88 (0.42, 1.85) |
| Pharyngeal (n=61) | 31 | 1.80 (1.03, 3.15) | 8 | 1.59 (0.69, 3.66) |
| Soft tissue (n=45) | 18 | 1.25 (0.65, 2.38) | 6 | 1.42 (0.56, 3.63) |
| *Other diseases¶:* | | | | |
| **Autoimmune** | | | | |
| Lupus (n=69) | 27 | 0.96 (0.58, 1.59) | 6 | 0.90 (0.37, 2.17) |
| Scleroderma‖ (n=15) | 8 | 1.67 (0.58, 4.82) | 1 | 0.83 (0.10, 6.94) |
| **Nervous system** | | | | |
| Amyotrophic lateral sclerosis (ALS)‡ (n=38) | 14 | 0.97 (0.48, 1.97) | 6 | 1.67 (0.65, 4.25) |
| Multiple sclerosis (n=117) | 45 | 1.01 (0.68, 1.51) | 16 | 1.46 (0.82, 2.59) |
| Parkinson disease (n=78) | 34 | 1.00 (0.63, 1.59) | 3 | 0.33 (0.10, 1.09) |
| **Male reproductive organs** | | | | |
| Infertility (n=129) | 54 | 1.06 (0.73, 1.53) | 11 | 0.86 (0.45, 1.66) |
| *Low testosterone (n=36)* | 15 | 1.10 (0.55, 2.22) | 4 | 1.18 (0.39, 3.53) |
| **Female reproductive organs** | | | | |

| Outcome | Medium exposure | | High exposure | |
|---|---|---|---|---|
| | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** |
| Endometriosis (n=84) | 10 | 0.80 (0.38, 1.67) | 11 | 1.29 (0.62, 2.70) |
| Infertility (n=105) | 12 | 0.75 (0.38, 1.47) | 12 | 1.10 (0.54, 2.22) |
| | | | | |
| **Other** | | | | |
| Aplastic anemia[I] (n=23) | 11 | 1.25 (0.54, 2.90) | 1 | 0.45 (0.06, 3.53) |
| Kidney disease (n=268) | 127 | 1.34 (1.02, 1.75) | 26 | 1.03 (0.66, 1.62) |
| *End stage renal[I] (n=87)* | 42 | 1.38 (0.88, 2.16) | 8 | 1.05 (0.48, 2.28) |
| *Glomerulonephritis[I] (n=38)* | 23 | 2.21 (1.12, 4.39) | 2 | 0.77 (0.17, 3.43) |
| *Nephrotic syndrome[‡] (n=63)* | 22 | 0.81 (0.47, 1.39) | 7 | 1.03 (0.45, 2.35) |
| *Renal failure (n=136)* | 68 | 1.48 (1.02, 2.12) | 12 | 0.99 (0.52, 1.88) |
| *Renal sclerosis[‡] (n=17)* | 9 | 1.25 (0.47, 3.34) | 1 | 0.63 (0.08, 5.02) |
| Liver disease (n=456) | 216 | 1.37 (1.10, 1.69) | 48 | 1.15 (0.81, 1.62) |
| *Cirrhosis[‡] (n=77)* | 36 | 1.32 (0.82, 2.13) | 7 | 1.03 (0.45, 2.35) |
| *Fatty liver (n=359)* | 171 | 1.38 (1.09, 1.75) | 38 | 1.17 (0.80, 1.71) |
| *Liver failure[‡] (n=22)* | 7 | 0.73 (0.29, 1.86) | 3 | 1.25 (0.35, 4.46) |

**Abbreviations:** TCE = trichloroethylene; OR = odds ratio; CI = confidence interval.
*All causes of cancer adjusted for age as a categorical variable and sex except for sex-specific outcomes unless otherwise noted.
†Adjusted for age only.
‡ Men only are included in the analysis (no cases among women).
[§]Adjusted for age as a continuous variable.
[I] Unadjusted results.
[¶]All analyses adjusted for sex except for sex-specific outcomes unless otherwise noted
Note: the reference level is low exposure among Camp Lejeune Marines.

**Table 10. Odds ratios for internal analyses of cumulative exposure to PCE among Camp Lejeune Marines**

| Outcome | Medium exposure | | High exposure | |
|---|---|---|---|---|
| | No. | OR (95% CI) | No. | OR (95% CI) |
| *Cancers*:* | | | | |
| **Digestive organs** | | | | |
| Colon (n=246) | 70 | 0.75 (0.55, 1.02) | 40 | 1.48 (1.01, 2.19) |
| Esophageal †,‡ (n=52) | 18 | 0.89 (0.48, 1.66) | 8 | 1.57 (0.70, 3.54) |
| Liver† (n=49) | 29 | 2.30 (1.22, 4.33) | 4 | 1.26 (0.42, 3.84) |
| Pancreatic (n=66) | 18 | 0.74 (0.41, 1.33) | 10 | 1.35 (0.65, 2.77) |
| Rectal (n=59) | 23 | 1.12 (0.63, 1.98) | 8 | 1.43 (0.64, 3.21) |
| **Hematopoietic** | | | | |
| Leukemia (n=125) | 39 | 0.76 (0.51, 1.15) | 14 | 0.98 (0.54, 1.79) |
| Lymphomas (n=232) | 97 | 1.21 (0.90, 1.63) | 24 | 1.14 (0.71, 1.84) |
| Multiple myeloma †,‡ (n=48) | 20 | 1.34 (0.71, 2.54) | 6 | 1.35 (0.54, 3.40) |
| **Respiratory system** | | | | |
| Laryngeal (n=40) | 17 | 2.01 (0.96, 4.19) | 9 | 3.26 (1.37, 7.72) |
| Lung (n=299) | 92 | 0.82 (0.62, 1.08) | 42 | 1.23 (0.84, 1.78) |
| **Sex-specific** | | | | |
| Breast (male) § (n=12) | 7 | 2.19 (0.64, 7.49) | 1 | 1.26 (0.14, 11.3) |
| Breast (female)† (n=109) | 13 | 0.86 (0.43, 1.73) | 14 | 1. 51 (0.73, 3.09) |
| Cervical§ (n=18) | 3 | 1.08 (0.30, 3.90) | 1 | 0.52 (0.06, 4.15) |
| Prostate† (n=903) | 295 | 0.95 (0.79, 1.13) | 134 | 1.37 (1.06, 1.76) |
| **Urinary system** | | | | |
| Bladder (n=182) | 59 | 0.99 (0.69, 1.40) | 30 | 1.54 (0.99, 2.41) |
| Kidney (n=192) | 80 | 1.43 (1.02, 2.00) | 32 | 2.01 (1.29, 3.13) |
| **Other** | | | | |
| Brain (n=90) | 36 | 1.17 (0.74, 1.86) | 11 | 1.46 (0.73, 2.92) |
| Pharyngeal (n=61) | 30 | 1.36 (0.79, 2.34) | 4 | 0.71 (0.24, 2.05) |
| Soft tissue (n=45) | 17 | 1.23 (0.63, 2.41) | 8 | 2.15 (0.92, 5.03) |
| *Other diseases‖:* | | | | |
| **Autoimmune** | | | | |
| Lupus (n=69) | 29 | 1.10 (0.66, 1.82) | 6 | 0.98 (0.40, 2.37) |
| Scleroderma§ (n=15) | 8 | 1.67 (0.58, 4.82) | 1 | 0.83 (0.10, 6.94) |
| **Nervous system** | | | | |
| Amyotrophic lateral sclerosis (ALS)‡ (n=38) | 9 | 0.59 (0.27, 1.31) | 10 | 2.63 (1.21, 5.73) |
| Multiple sclerosis (n=117) | 53 | 1.15 (0.79, 1.69) | 6 | 0.53 (0.23, 1.24) |
| Parkinson disease (n=78) | 21 | 0.57 (0.34, 0.97) | 13 | 1.32 (0.70, 2.49) |
| **Male reproductive organs** | | | | |
| Infertility (n=129) | 44 | 0.74 (0.51, 1.09) | 11 | 0.74 (0.39, 1.42) |
| *Low testosterone (n=36)* | 12 | 0.75 (0.36, 1.54) | 4 | 1.00 (0.34, 2.95) |
| **Female reproductive organs** | | | | |
| Endometriosis (n=84) | 15 | 1.28 (0.67, 2.44) | 10 | 1.26 (0.57, 2.69) |

| Outcome | Medium exposure | | High exposure | |
|---|---|---|---|---|
| | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** |
| Infertility (n=105) | 18 | 1.19 (0.66, 2.17) | 11 | 1.07 (0.52, 2.22) |
| **Other** | | | | |
| Aplastic anemia (n=23) | 9 | 1.07 (0.44, 2.66) | 4 | 1.74 (0.54, 5.59) |
| Kidney disease (n=268) | 122 | 1.35 (1.03, 1.77) | 37 | 1.51 (1.02, 2.26) |
| *End stage renal (n=87)* | 39 | 1.29 (0.82, 2.05) | 12 | 1.45 (0.74, 2.83) |
| *Glomerulonephritis (n=38)* | 23 | 2.55 (1.24, 5.25) | 4 | 1.67 (0.53, 5.31) |
| *Nephrotic syndrome ‡ (n=63)* | 26 | 1.30 (0.75, 2.27) | 12 | 2.40 (1.19, 4.84) |
| *Renal failure (n=136)* | 62 | 1.42 (0.97, 2.07) | 21 | 1.80 (1.07, 3.05) |
| *Renal sclerosis‡ (n=17)* | 6 | 0.94 (0.32, 2.71) | 3 | 1.87 (0.49, 7.11) |
| Liver disease (n=456) | 205 | 1.27 (1.02, 1.57) | 56 | 1.29 (0.93, 1.79) |
| *Cirrhosis‡ (n=77)* | 34 | 1.25 (0.77, 2.02) | 9 | 1.32 (0.63, 2.80) |
| *Fatty liver (n=359)* | 158 | 1.24 (0.97, 1.57) | 47 | 1.37 (0.96, 1.96) |
| *Liver failure (n=22)* | 9 | -- | 0 | -- |

**Abbreviations:** PCE = tetrachloroethylene; OR = odds ratio; CI = confidence interval.
*All causes of cancer adjusted for age as a categorical variable and sex unless otherwise noted.
†Adjusted for age only.
‡ Men only are included in the analysis. (No cases among women).
§Unadjusted results.
lAll analyses adjusted for sex except for sex-specific outcomes unless otherwise noted.
Note: the reference level is low exposure among Camp Lejeune Marines.

**Table 11. Odds ratios comparing Camp Lejeune workers with Camp Pendleton workers (referent)**

| Outcome | Camp Lejeune cases No., % | Camp Pendleton cases No., % | OR (95% CI) |
|---|---|---|---|
| *Cancers*:* | | | |
| **Digestive organs** | | | |
| Colon | 26, 1.49 | 12, 0.99 | 1.49 (0.75, 2.96) |
| Esophageal | 4, 0.23 | 3, 0.25 | 0.89 (0.20, 3.98) |
| Liver | 2, 0.12 | 5, 0.42 | 0.31 (0.06, 1.58) |
| Pancreatic | 8, 0.46 | 7, 0.58 | 0.80 (0.29, 2.22) |
| Rectal | 6, 0.35 | 3, 0.25 | 1.41 (0.35, 5.65) |
| **Hematopoietic** | | | |
| Leukemia | 8, 0.46 | 5, 0.42 | 1.10 (0.36, 3.38) |
| Lymphomas | 18, 1.04 | 10, 0.83 | 1.28 (0.59, 2.79) |
| Multiple myeloma† | 4, 0.23 | 2, 0.17 | 1.57 (0.29, 8.62) |
| **Respiratory system** | | | |
| Laryngeal | 2, 0.12 | 1, 0.08 | 1.42 (0.13, 15.73) |
| Lung | 39, 2.22 | 18, 1.48 | 1.59 (0.91, 2.80) |
| **Sex-specific** | | | |
| Breast (male) | 1, 0.14 | 1, 0.17 | 0.78 (0.05, 12.58) |
| Breast (female) | 94, 8.54 | 28, 4.35 | 2.09 (1.34, 3.26) |
| Cervical | 2, 0.20 | 5, 0.81 | 0.24 (0.04, 1.31) |
| Prostate | 72, 9.21 | 46, 7.31 | 1.28 (0.87, 1.89) |
| **Urinary system** | | | |
| Bladder | 13, 0.75 | 11, 0.91 | 0.82 (0.37, 1.84) |
| Kidney | 20, 1.15 | 9, 0.75 | 1.52 (0.69, 3.35) |
| **Other** | | | |
| Brain | 6, 0.35 | 1, 0.08 | 4.01 (0.48, 33.38) |
| Pharyngeal | 2, 0.12 | 0, 0.0 | -- |
| Soft tissue‡ | 2, 0.28 | 0, 0.0 | -- |
| *Other diseases:* | | | |
| **Autoimmune** | | | |
| Lupus | 7, 0.41 | 2, 0.17 | 2.44 (0.51, 11.77) |
| Scleroderma | 2, 0.12 | 1, 0.08 | 1.40 (0.13, 15.40) |
| **Nervous system** | | | |
| Amyotrophic lateral sclerosis (ALS) ‡ | 0 | 1, 0.16 | -- |
| Multiple sclerosis | 7, 0.41 | 1, 0.08 | 4.88 (0.60, 39.75) |
| Parkinson disease† | 20, 1.15 | 5, 0.42 | 3.11 (1.16, 8.32) |
| **Male reproductive organs** | | | |
| Infertility | 2, 0.28 | 0 | -- |
| *Abnormal sperm* | 0 | 0 | -- |

| Outcome | Camp Lejeune cases No., % | Camp Pendleton cases No., % | OR (95% CI) |
|---|---|---|---|
| *Epididymitis* | 0 | 0 | -- |
| *Low sperm count* | 0 | 0 | -- |
| *Low testosterone* | 1, 0.14 | 0 | -- |
| **Female reproductive organs** | | | |
| Endometriosis | 30, 2.89 | 10, 1.60 | 1.83 (0.89, 3.77) |
| Infertility | 34, 2.27 | 10, 1.60 | 2.08 (1.02, 4.23) |
| *Amenorrhea* | 0 | 0 | -- |
| *Fallopian tube damage* | 2, 0.20 | 0 | -- |
| *Ovulation disorder* | 1, 0.10 | 1, 0.16 | 0.61 (0.04, 9.78) |
| **Other** | | | |
| Aplastic anemia‡ | 2, 0.20 | 0 | -- |
| Kidney disease | 17, 0.98 | 10, 0.83 | 1.19 (0.54, 2.60) |
| *End stage renal†* | 9, 0.52 | 3, 0.25 | 2.35 (0.63, 8.72) |
| *Glomerulonephritis* | 5, 0.29 | 0 | -- |
| *Goodpastures syndrome* | 0 | 0 | -- |
| *Nephrotic syndrome* | 6, 0.35 | 2, 0.17 | 2.09 (0.42, 10.39) |
| *Renal failure* | 2, 0.12 | 5, 0.42 | 0.28 (0.05, 1.44) |
| *Renal sclerosis* | 4, 0.23 | 2, 0.17 | 1.40 (0.26, 7.63) |
| Liver disease | 17, 0.98 | 11, 0.91 | 1.08 (0.50, 2.31) |
| *Biliary cirrhosis‡* | 2, 0.20 | 1, 0.16 | 1.22 (0.11, 13.50) |
| *Cirrhosis* | 4, 0.23 | 1, 0.08 | 2.79 (0.31, 24.99) |
| *Fatty liver* | 12, 0.69 | 9, 0.75 | 0.93 (0.39, 2.22) |
| *Hepatomegaly* | 0 | 0 | -- |
| *Liver failure* | 2, 0.12 | 0 | -- |
| *Necrosis* | 0 | 0 | -- |
| TCE-related skin disorder‡ | 2, 0.28 | 0, 0.0 | -- |

**Abbreviations:** TCE = trichloroethylene; OR = odds ratio; CI = confidence interval.
*All causes of cancer adjusted for age at diagnosis.

†Adjusted for sex.

‡Soft tissue cancer and TCE-related skin disease were reported only in men. ALS, aplastic anemia, and biliary cirrhosis were reported only in women.

**Table 12. Odds ratios for cumulative TCE/PCE* exposure in workers at Camp Lejeune compared with those at Camp Pendleton (referent)**

| Outcome | Low exposure | | Medium exposure | | High exposure | |
|---|---|---|---|---|---|---|
| | No. | OR (95% CI) | No. | OR (95% CI) | No. | OR (95% CI) |
| *Cancers†:* | | | | | | |
| **Digestive organs** | | | | | | |
| Colon (n=38) | 11 | 1.15 (0.50, 2.66) | 8 | 1.30 (0.53, 3.23) | 7 | 4.74 (1.77, 12.68) |
| Pancreatic (n=15) | 2 | 0.40 (0.08, 1.93) | 3 | 0.76 (0.20, 2.94) | 3 | 2.84 (0.73, 11.07) |
| Rectal (n=9) | 2 | 0.93 (0.16, 5.58) | 1 | 0.59 (0.06, 5.67) | 3 | 6.62 (1.33, 33.04) |
| **Hematopoietic** | | | | | | |
| Leukemia (n=13) | 3 | 0.84 (0.20, 3.52) | 4 | 1.41 (0.38, 5.28) | 1 | 1.32 (0.15, 11.40) |
| Lymphomas (n=28) | 6 | 0.99 (0.35, 2.78) | 9 | 1.70 (0.68, 4.24) | 3 | 1.71 (0.46, 6.39) |
| Multiple myeloma (n=6) | 1 | 0.70 (0.06, 7.71) | 2 | 1.77 (0.25, 12.57) | 1 | 3.31 (0.30, 36.68) |
| **Respiratory system** | | | | | | |
| Lung (n=57) | 14 | 1.38 (0.67, 2.85) | 20 | 1.90 (1.00, 3.62) | 5 | 1.50 (0.55, 4.11) |
| **Sex-specific** | | | | | | |
| Breast (female) (n=122) | 40 | 1.42 (0.83, 2.42) | 42 | 3.02 (1.78, 5.15) | 12 | 5.09 (2.37, 10.96) |
| Prostate (n=118) | 24 | 0.98 (0.58, 1.64) | 21 | 1.15 (0.67, 1.97) | 27 | 2.40 (1.43, 4.02) |
| **Urinary system** | | | | | | |
| Bladder (n=24) | 8 | 1.02 (0.41, 2.54) | 2 | 0.32 (0.07, 1.45) | 3 | 1.81 (0.50, 6.53) |
| Kidney (n=29) | 3 | 0.34 (0.09, 1.25) | 8 | 1.80 (0.68, 4.76) | 9 | 13.92 (5.09, 38.10) |
| *Other diseases:* | | | | | | |
| **Autoimmune** | | | | | | |
| Lupus (n=9) | 1 | 0.70 (0.06, 7.71) | 5 | 4.42 ( 0.86, 22.83) | 1 | 3.31 (0.30, 36.68) |
| **Nervous system** | | | | | | |
| Multiple sclerosis (n=8) | 3 | 4.18 (0.44, 40.34) | 3 | 5.30 (0.55, 51.06) | 1 | 6.62 (0.41, 106.28) |
| Parkinson disease‡ (n=25) | 7 | 2.78 (0.87, 8.94) | 10 | 3.47 (1.18, 10.22) | 3 | 2.86 (0.67, 12.13) |
| **Female reproductive organs** | | | | | | |
| Endometriosis (n=40) | 13 | 1.59 (0.69, 3.66) | 16 | 2.44 (1.10, 5.43) | 1 | 0.60 (0.08, 4.76) |
| Infertility (female) (n=44) | 16 | 1.96 (0.88, 4.36) | 17 | 2.59 (1.18, 5.72) | 1 | 0.60 (0.08, 4.76) |
| **Other** | | | | | | |
| Kidney disease (n=27) | 4 | 0.56 (0.18, 1.79) | 9 | 1.59 ( 0.64, 3.93) | 4 | 2.65 (0.82, 8.53) |
| *End stage renal (n=12)* | 1 | 0.47 (0.05, 4.48) | 6 | 3.53 (0.88, 14.18) | 2 | 4.41 ( 0.73, 26.59) |
| *Nephrotic syndrome (n=8)* | 3 | 2.09 (0.35, 12.56) | 2 | 1.77 (0.25, 12.57) | 1 | 3.31 (0.30, 36.68) |
| Liver disease (n=28) | 10 | 1.27 (0.54, 3.00) | 6 | 0.96 (0.36, 2.62) | 1 | 0.60 (0.08, 4.69) |
| *Fatty liver (n=21)* | 8 | 1.24 (0.48, 3.23) | 3 | 0.59 (0.16, 2.18) | 1 | 0.74 (0.09, 5.84) |

**Abbreviations:** TCE = trichloroethylene; PCE = tetrachloroethylene; OR = odds ratio; CI = confidence interval.

*The correlation between TCE and PCE is approximately 1.

†All causes of cancer adjusted for age at diagnosis if >2 cases per cell.

‡Adjusted for sex.
Note: the numbers in parentheses after the diseases are the total number of cases at both bases.

**Table 13. Odds ratios* for the internal analyses of cumulative exposure to TCE/PCE† among Camp Lejeune civilian employees**

| Outcome | Medium exposure | | High exposure | |
|---|---|---|---|---|
| | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** |
| *Cancers‡:* | | | | |
| **Digestive organs** | | | | |
| Colon (n=26) | 8 | 1.24 (0.48, 3.19) | 7 | 5.47 (1.86, 16.10) |
| Esophageal (n=4) | 2 | -- | 0 | -- |
| Liver (n=2) | 1 | -- | 0 | -- |
| Pancreatic (n=8) | 3 | 2.52 (0.40, 15.72) | 3 | 12.48 (1.72, 90.46) |
| Rectal§ (n=6) | 1 | 0.63 (0.06, 6.99) | 3 | 7.11 (1.18, 42.90) |
| **Hematopoietic** | | | | |
| Leukemia§ (n=8) | 4 | 1.69 (0.38, 7.57) | 1 | 1.58 (0.16, 15.30) |
| Lymphomas (n=18) | 9 | 1.64 (0.56, 4.83) | 3 | 1.86 (0.43, 8.11) |
| Multiple myeloma§ (n=4) | 2 | 3.13 (0.28, 34.70) | 1 | 2.72 (0.17, 43.80) |
| **Respiratory system** | | | | |
| Laryngeal (n=2) | 0 | -- | 0 | -- |
| Lung (n=39) | 20 | 1.39 (0.68, 2.85) | 5 | 1.10 (0.38, 3.22) |
| **Sex-specific** | | | | |
| Breast (male) (n=1) | 1 | -- | 0 | -- |
| Breast (female) (n=94) | 42 | 1.97 (1.22, 3.18) | 12 | 5.09 (2.34, 11.10) |
| Cervical (n=2) | 1 | -- | 0 | -- |
| Prostate (n=72) | 21 | 1.16 (0.62, 2.16) | 27 | 2.42 (1.32, 4.44) |
| **Urinary system** | | | | |
| Bladder§ (n=13) | 2 | 0.32 (0.07, 1.50) | 3 | 1.78 (0.47, 6.77) |
| Kidney (n=20) | 8 | 5.34 (1.38, 20.6) | 9 | 41.54 (10.20, 169.23) |
| **Other** | | | | |
| Brain (n=6) | 6 | -- | 0 | -- |
| Pharyngeal (n=2) | 1 | -- | 1 | -- |
| Soft tissue (n=2) | 0 | -- | 0 | -- |
| *Other diseases§:* | | | | |
| **Autoimmune** | | | | |
| Lupus (n=7) | 5 | 6.33 (0.74, 54.30) | 1 | 4.74 (0.30, 76.10) |
| Scleroderma (n=2) | 2 | -- | 0 | -- |
| **Nervous system** | | | | |
| Amyotrophic lateral sclerosis (ALS) (n=0) | 0 | -- | 0 | -- |
| Multiple sclerosis (n=7) | 3 | 1.27 (0.25, 6.29) | 1 | 1.58 (0.16, 15.3) |
| Parkinson disease (n=20) | 10 | 1.81 (0.69, 4.77) | 3 | 2.03 (0.52, 7.93) |
| **Male reproductive organs** | | | | |
| Infertility (n=2) | 0 | -- | 1 | -- |
| *Low testosterone (n=1)* | 0 | -- | 1 | -- |
| **Female reproductive organs** | | | | |

| Outcome | Medium exposure | | High exposure | |
|---|---|---|---|---|
| | **No.** | **OR (95% CI)** | **No.** | **OR (95% CI)** |
| Endometriosis (n=30) | 16 | 1.53 (0.73, 3.22) | 1 | 0.38 (0.05, 2.93) |
| Infertility (female) (n=34) | 17 | 1.32 (0.66, 2.65) | 1 | 0.31 (0.04, 2.35) |
| *Fallopian tube damage (n=2)* | 1 | -- | 0 | -- |
| *Ovulation disorder (n=1)* | 1 | -- | 0 | -- |
| **Other** | | | | |
| Aplastic anemia (n=2) | 0 | -- | 1 | -- |
| Kidney disease (n=17) | 9 | 2.85 (0.87, 9.29) | 4 | 4.74 (1.18, 19.10) |
| *End stage renal (n=9)* | 6 | 7.59 (0.91, 63.2) | 2 | 9.48 (0.86, 105) |
| *Glomerulonephritis (n=5)* | 1 | 0.63 (0.06, 6.99) | 2 | 4.74 (0.66, 33.9) |
| *Nephrotic syndrome (n=6)* | 2 | 0.84 (0.14, 5.06) | 1 | 1.58 (0.16, 15.3) |
| *Renal failure (n=2)* | 2 | -- | 0 | -- |
| *Renal sclerosis (n=4)* | 1 | -- | 0 | -- |
| Liver disease (n=17) | 6 | 0.76 (0.27, 2.10) | 1 | 0.47 (0.06, 3.73) |
| *Cirrhosis (n=4)* | 2 | -- | 0 | -- |
| *Fatty liver (n=12)* | 3 | 0.47 (0.13, 1.80) | 1 | 0.59 (0.07, 4.77) |
| *Liver failure (n=2)* | 1 | -- | 0 | -- |

**Abbreviations:** TCE = trichloroethylene; PCE = tetrachloroethylene; OR = odds ratio; CI = confidence interval.

*ORs were not calculated if both cells had <2 cases or one cell had zero cases.

[†]The correlation between TCE and PCE is approximately 1.

[‡]All causes of cancers were adjusted for age as a continuous variable unless otherwise noted.

[§]Unadjusted.

Note: the reference level is low exposure among Camp Lejeune civilian employees.

**Table 14. Characteristics of Marine and civilian worker participants and non-participants***

| Characteristic | Marines | | | | Civilian workers | | | |
|---|---|---|---|---|---|---|---|---|
| | Participants | | Non-participants | | Participants | | Non-participants | |
| | CL % | CP % | CL % | CP % | CL % | CP % | CL % | CP % |
| **Education attained by 1987** | | | | | | | | |
| Less than high school | 11 | 9 | 16 | 15 | 22 | 22 | 25 | 26 |
| High school graduate | 74 | 70 | 76 | 73 | 19 | 21 | 22 | 23 |
| Some college or technical school | 6 | 8 | 4 | 6 | 39 | 48 | 38 | 43 |
| Bachelor's degree or higher | 10 | 13 | 4 | 6 | 21 | 10 | 16 | 8 |
| **Race** | | | | | | | | |
| White | 80 | 85 | 73 | 78 | 81 | 81 | 76 | 74 |
| Black | 18 | 12 | 24 | 16 | 15 | 7 | 19 | 9 |
| Other | 2 | 4 | 3 | 5 | 4 | 12 | 5 | 17 |
| Missing | <1 | <1 | <1 | <1 | 0 | 0 | 0 | 0 |
| **Sex** | | | | | | | | |
| Male | 95 | 81 | 96 | 87 | 40.9 | 47 | 47 | 51 |
| Female | 6 | 19 | 4 | 13 | 59.1 | 53 | 53 | 49 |
| **Age of those alive in 2011*** | | | | | | | | |
| <50 years | 24 | 22 | 30 | 28 | 3.0 | 3 | 4 | 4 |
| ≥50-<60 years | 61 | 60 | 62 | 63 | 30 | 27 | 36 | 30 |
| ≥60-<70 years | 11 | 13 | 6 | 8 | 36 | 30 | 33 | 29 |
| ≥70 years | 4 | 5 | 2 | 2 | 31 | 40 | 27 | 37 |
| **Highest rank by 1987** | | | | | | | | |
| Private to Gunnery Sergeant | 87 | 83 | 94 | 92 | | | | |
| Sergeant (Master, First, Major) | 3 | 2 | 2 | 2 | | | | |
| Warrant Officer | <1 | <1 | <1 | <1 | | | | |
| Commissioned Officer | 10 | 14 | 4 | 6 | | | | |

**Abbreviations:** CL = Camp Lejeune; CP= Camp Pendleton.
*Using initial sample before reclassification based on survey responses.

**Table 15. Sensitivity analysis comparing estimated exposures for those Marines in the mortality study who did and did not participate in the health survey**

| | Participants | | Non-participants | |
|---|---|---|---|---|
| **Exposure*** | **Mean** | **Median** | **Mean** | **Median** |
| Mean TVOC (µg/L) | 312.5 | 223.6 | 322.4 | 292.6 |
| Mean PCE (µg/L) | 12.2 | 11.7 | 12.1 | 12.2 |
| Mean TCE (µg/L) | 208.3 | 236.3 | 213.6 | 280.3 |
| Cumulative TVOC (µg/L-months) | 6527.0 | 2049.6 | 6019.9 | 1807.3 |
| Cumulative PCE (µg/L-months) | 253.0 | 64.0 | 226.6 | 56.9 |
| Cumulative TCE (µg/L-months) | 4000.2 | 1133.6 | 3695.5 | 1081.8 |

**Abbreviations**: TVOC = total volatile organic compounds; PCE = tetrachloroethylene; TCE = trichloroethylene; µg/L = micrograms per liter.

*Mean monthly exposure during periods when the individual was exposed

**Table 16. Conditions reported by Camp Lejeune and Camp Pendleton Marines and civilian workers, by HIPAA form completion**

| Outcome | Marines with Complete HIPAA forms | | Civilian workers with Complete HIPAA forms | |
|---|---|---|---|---|
| | Camp Lejeune % | Camp Pendleton % | Camp Lejeune % | Camp Pendleton % |
| *Cancers:* | | | | |
| **Digestive organs** | | | | |
| Colon | 68.5 | 64.0 | 77.5 | 66.7 |
| Esophageal | 74.5 | 45.0 | 62.5 | 66.7 |
| Liver | 55.6 | 44.6 | 73.3 | 69.2 |
| Pancreatic | 70.5 | 47.8 | 100.0 | 85.7 |
| Rectal | 63.3 | 64.7 | 77.8 | 75.0 |
| **Hematopoietic** | | | | |
| Leukemia | 86.0 | 82.9 | 81.8 | 85.7 |
| Lymphomas | 79.8 | 69.1 | 85.2 | 75.0 |
| Multiple myeloma | 75.4 | 60.0 | 85.7 | 42.9 |
| **Respiratory system** | | | | |
| Laryngeal | 68.7 | 41.7 | 100.0 | 50.00 |
| Lung | 71.8 | 65.1 | 90.0 | 84.9 |
| **Sex-specific** | | | | |
| Breast (male) | 53.5 | 16.7 | 50.0 | 100.0 |
| Breast (female) | 74.8 | 73.1 | 84.0 | 70.4 |
| Cervical | 50.9 | 50.0 | 63.2 | 50.0 |
| Prostate | 71.2 | 63.9 | 77.5 | 71.8 |
| **Urinary system** | | | | |
| Bladder | 73.0 | 77.8 | 69.6 | 86.7 |
| Kidney | 68.1 | 68.3 | 88.0 | 83.3 |
| **Other** | | | | |
| Brain | 67.0 | 74.4 | 100.0 | 33.3 |
| Pharyngeal | 58.6 | 41.4 | 83.3 | 60.0 |
| Soft tissue | 59.7 | 54.6 | 100.0 | 57.1 |
| *Other diseases:* | | | | |
| **Autoimmune** | | | | |
| Lupus | 49.7 | 38.0 | 48.3 | 45.5 |
| Scleroderma | 42.3 | 48.2 | 55.6 | 20.0 |
| **Nervous system** | | | | |
| Amyotrophic lateral sclerosis (ALS) | 47.7 | 60.0 | 70.0 | 75.0 |
| Multiple sclerosis | 57.9 | 53.6 | 57.1 | 57.1 |
| Parkinson disease | 56.2 | 62.8 | 85.2 | 72.7 |
| **Reproductive organs** | | | | |
| Endometriosis | 50.5 | 46.2 | 49.2 | 40.8 |

| Outcome | Marines with Complete HIPAA forms | | Civilian workers with Complete HIPAA forms | |
|---|---|---|---|---|
| | Camp Lejeune % | Camp Pendleton % | Camp Lejeune % | Camp Pendleton % |
| Infertility (male) | 61.1 | 70.4 | 31.8 | 71.4 |
| Infertility (female) | 51.3 | 62.7 | 61.4 | 61.5 |
| **Other** | | | | |
| Aplastic anemia | 55.1 | 51.9 | 68.2 | 30.8 |
| Kidney disease | 57.2 | 46.8 | 65.9 | 57.3 |
| Liver disease | 52.5 | 42.4 | 58.3 | 62.2 |
| TCE-related skin disorder | 47.7 | 36.4 | 35.3 | 25.0 |

**Abbreviations**: HIPAA = Health Insurance Portability and Accountability Act; TCE = trichloroethylene.

**Table 17. Confirmation of reported conditions among Marines and civilian workers at Camp Lejeune and Camp Pendleton among those with completed HIPAA forms**

| Outcome | Marines | | Civilian | |
|---|---|---|---|---|
| | CL % | CP % | CL % | CP % |
| *Cancers:* | | | | |
| **Digestive organs** | | | | |
| Colon | 74.2 | 91.5 | 92.9 | 92.9 |
| Esophageal | 58.4 | 75.0 | 100.0 | 100.0 |
| Liver | 50.0 | 66.7 | 50.00 | 83.3 |
| Pancreatic | 87.3 | 80.0 | 100.0 | 100.0 |
| Rectal | 76.7 | 80.0 | 85.7 | 100.0 |
| **Hematopoietic** | | | | |
| Leukemia | 90.3 | 89.3 | 88.9 | 100.0 |
| Lymphomas | 82.4 | 88.2 | 81.8 | 90.9 |
| Multiple myeloma | 53.3 | 36.4 | 66.7 | 66.7 |
| **Respiratory system** | | | | |
| Laryngeal | 86.7 | 100.0 | 100.0 | 50.0 |
| Lung | 86.3 | 85.5 | 95.2 | 84.0 |
| **Sex-specific** | | | | |
| Breast (male) | 55.0 | 100.0 | 100.0 | 100.0 |
| Breast (female) | 96.1 | 96.9 | 96.9 | 97.1 |
| Cervical | 42.5 | 35.7 | 25.0 | 71.4 |
| Prostate | 96.1 | 98.2 | 97.3 | 96.0 |
| **Urinary system** | | | | |
| Bladder | 91.4 | 96.7 | 81.3 | 100.0 |
| Kidney | 85.6 | 94.1 | 95.2 | 71.4 |
| **Other** | | | | |
| Brain | 75.9 | 76.2 | 85.7 | 100.0 |
| Pharyngeal | 82.4 | 80.0 | 50.0 | 0.0 |
| Soft tissue | 39.1 | 34.8 | 40.0 | 0.0 |
| *Other diseases:* | | | | |
| **Autoimmune** | | | | |
| Lupus | 52.8 | 60.9 | 58.3 | 50.0 |
| Scleroderma | 19.5 | 36.8 | 50.0 | 100.0 |
| **Nervous system** | | | | |
| Amyotrophic lateral sclerosis (ALS) | 39.2 | 34.8 | 0.0 | 33.3 |
| Multiple sclerosis | 81.6 | 75.7 | 100.0 | 100.0 |
| Parkinson disease | 67.9 | 68.0 | 95.2 | 100.0 |
| **Reproductive organs** | | | | |
| Endometriosis | 44.2 | 48.0 | 49.2 | 40.0 |
| Infertility (male) | 27.6 | 21.7 | 20.0 | 0.0 |

| Outcome | Marines | | Civilian | |
|---|---|---|---|---|
| | CL % | CP % | CL % | CP % |
| Infertility (female) | 49.3 | 32.3 | 57.9 | 23.1 |
| **Other** | | | | |
| Aplastic anemia | 11.9 | 19.4 | 20.0 | 25.0 |
| Kidney disease | 69.9 | 74.3 | 78.1 | 97.0 |
| Liver disease | 61.1 | 63.5 | 58.8 | 72.7 |
| TCE-related skin disorder | 25.3 | 25.0 | 33.3 | 0.0 |

**Abbreviations**: HIPAA = Health Insurance Portability and Accountability Act; TCE = trichloroethylene, CL=Camp Lejeune, CP= Camp Pendleton.

**Table 18. Descriptive data for dependent children from the 1999-2002 ATSDR survey, Camp Lejeune**

| Characteristic (n=1847) | No. | % |
|---|---|---|
| **Race*** | | |
| White | 1518 | 81.7 |
| Black | 217 | 11.7 |
| Other | 122 | 6.65 |
| **Sex** | | |
| Male | 710 | 38.4 |
| Female | 1136 | 61.5 |
| Missing | 1 | <0.01 |
| **Education** | | |
| High school graduate | 1752 | 94.9 |
| Not a high school graduate | 37 | 2.0 |
| Missing | 58 | 3.1 |
| **Age at survey** | | |
| 26-29 years | 289 | 15.7 |
| 30-34 years | 508 | 27.5 |
| 35-39 years | 518 | 28.1 |
| 40-43 years | 532 | 28.8 |
| **Worked with pesticides** | 86 | 4.7 |
| **Worked with radiation** | 188 | 10.2 |
| **Worked with metals** | 88 | 4.8 |
| **Worked with solvents** | 206 | 11.2 |
| **Worked with other chemicals** | 143 | 7.7 |
| **Ever smoked cigarettes** | 770 | 41.7 |
| **Current number of alcoholic drinks** | | |
| Not a current drinker | 318 | 17.2 |
| <1 drink per month | 433 | 23.4 |
| 1-3 drinks per month | 368 | 19.9 |
| 1-4 drinks per week | 472 | 25.6 |
| Drinks daily or almost daily | 67 | 3.6 |
| Missing | 189 | 10.2 |
| **Confirmed diseases (n=1640†)** | | |
| *Cancers* | | |
| **Digestive organs** | | |
| Colon | 0 | 0 |
| Esophageal | 0 | 0 |
| Liver | 0 | 0 |
| Pancreatic | 0 | 0 |
| Rectal | 1 | 0.1 |
| **Hematopoietic** | | |
| Leukemia | 0 | 0 |

| **Characteristic (n=1847)** | **No.** | **%** |
|---|---|---|
| Lymphomas | 6 | 0.4 |
| Multiple myeloma | 0 | 0 |
| **Respiratory system** | | |
| Laryngeal | 0 | 0 |
| Lung | 0 | 0 |
| **Sex-specific** | | |
| Breast (male) | 0 | 0 |
| Breast (female) | 3 | 0.3 |
| Cervical | 4 | 0.4 |
| Prostate | 0 | 0 |
| **Urinary system** | | |
| Bladder | 0 | 0 |
| Kidney | 3 | 0.2 |
| **Other** | | |
| Brain | 3 | 0.2 |
| Pharyngeal | 0 | 0 |
| Soft tissue | 0 | 0 |
| *Non-cancer diseases* | | |
| **Autoimmune** | | |
| Lupus | 2 | 0.1 |
| Scleroderma | 0 | 0 |
| **Nervous system** | | |
| Amyotrophic lateral sclerosis (ALS) | 0 | 0 |
| Multiple sclerosis | 9 | 0.5 |
| Parkinson disease | 0 | 0 |
| **Male reproductive organs** | | |
| Infertility | 5 | 0.7 |
| *Abnormal sperm* | 2 | 0.3 |
| *Epididymitis* | 0 | 0 |
| *Low sperm count* | 5 | 0.7 |
| *Low testosterone* | 0 | 0 |
| **Female reproductive organs** | | |
| Endometriosis | 42 | 4.3 |
| Infertility | 71 | 7.3 |
| *Amenorrhea* | 1 | 0.1 |
| *Fallopian tube damage* | 6 | 0.6 |
| *Ovulation disorder* | 14 | 1.4 |
| **Other** | | |
| Aplastic anemia | 1 | <0.1 |
| Kidney disease | 5 | 0.3 |
| *End stage renal* | 3 | 0.2 |
| *Glomerulonephritis* | 1 | 0.1 |
| *Goodpastures syndrome* | 0 | 0 |

| **Characteristic (n=1847)** | **No.** | **%** |
|---|---|---|
| *Nephrotic syndrome* | 0 | 0 |
| *Renal failure* | 3 | 0.2 |
| *Renal sclerosis* | 0 | 0 |
| Liver disease | 10 | 0.6 |
| *Biliary cirrhosis* | 0 | 0 |
| *Cirrhosis* | 0 | 0 |
| *Fatty liver* | 10 | 0.5 |
| *Hepatomegaly* | 0 | 0 |
| *Liver failure* | 0 | 0 |
| *Necrosis* | 0 | 0 |
| TCE-related skin disorder | 0 | 0 |

**Abbreviations**: ATSDR = Agency for Toxic Substances and Disease Registry; TCE = trichloroethylene.

*Race is missing for 88 people; total is greater than the number of participants because more than one race could be reported.

†672 males and 958 females.

**Table 19. Descriptive data for adults* who participated in the 1999-2002 ATSDR survey, Camp Lejeune**

| Characteristic (n=4180) | No. | % |
|---|---|---|
| **Race**[†] | | |
| White | 3484 | 84.4 |
| Black | 447 | 10.8 |
| Other | 197 | 4.78 |
| **Sex** | | |
| Male | 1179 | 28.2 |
| Female | 2827 | 67.6 |
| Missing | 174 | 4.2 |
| **Education** | | |
| High school graduate | 3950 | 94.5 |
| Not a high school graduate | 132 | 3.2 |
| Missing | 98 | 2.3 |
| **Age at survey**[‡] | | |
| 44-54 years | 833 | 20.1 |
| 55-65 years | 2274 | 54.9 |
| 66-76 years | 940 | 22.7 |
| 77-88 years | 93 | 2.2 |
| Missing | 2 | ≤1.0 |
| **Served in Vietnam** | | |
| Served < 1 year | 147 | 3.5 |
| Served 1- <2 years | 395 | 9.4 |
| Served ≥ 2 years | 86 | 2.1 |
| **Worked with pesticides** | 389 | 9.3 |
| **Worked with radiation** | 536 | 12.8 |
| **Worked with metals** | 253 | 6.1 |
| **Worked with solvents** | 563 | 13.5 |
| **Worked with other chemicals** | 434 | 10.4 |
| **Ever smoked cigarettes** | 2208 | 52.8 |
| **Current number of alcoholic drinks** | | |
| Not a current drinker | 1325 | 31.7 |
| <1 drink per month | 746 | 17.9 |
| 1-3 drinks per month | 533 | 12.8 |
| 1-4 drinks per week | 755 | 18.1 |
| Drinks daily or almost daily | 300 | 7.2 |
| Missing | 521 | 12.5 |
| **Confirmed diseases (n=3623**[§]**)** | | |
| *Cancers* | | |
| **Digestive organs** | | |
| Colon | 34 | 0.9 |
| Esophageal | 4 | 0.1 |

| Characteristic (n=4180) | No. | % |
|---|---|---|
| Liver | 2 | <0.1 |
| Pancreatic | 5 | 0.1 |
| Rectal | 5 | 0.1 |
| **Hematopoietic** | | |
| Leukemia | 12 | 0.3 |
| Lymphomas | 18 | 0.5 |
| Multiple myeloma | 7 | 0.2 |
| **Respiratory system** | | |
| Laryngeal | 3 | 0.1 |
| Lung | 21 | 0.6 |
| **Sex-specific** | | |
| Breast (male)‖ | 0 | 0 |
| Breast (female)‖ | 108 | 4.4 |
| Cervical | 8 | 0.3 |
| Prostate | 76 | 6.7 |
| **Urinary system** | | |
| Bladder | 22 | 0.6 |
| Kidney | 15 | 0.4 |
| **Other** | | |
| Brain | 5 | 0.1 |
| Pharyngeal | 4 | 0.1 |
| Soft tissue | 3 | 0.1 |
| *Non-cancer diseases* | | |
| **Autoimmune** | | |
| Lupus | 7 | 0.2 |
| Scleroderma | 7 | 0.2 |
| **Nervous system** | | |
| Amyotrophic lateral sclerosis (ALS) | 0 | 0 |
| Multiple sclerosis | 13 | 0.4 |
| Parkinson disease | 10 | 0.3 |
| **Male reproductive organs** | | |
| Infertility | 1 | 0.1 |
| *Abnormal sperm* | 0 | 0 |
| *Low sperm count* | 0 | 0 |
| *Low testosterone* | 1 | 0.1 |
| **Female reproductive organs** | | |
| Endometriosis | 59 | 2.4 |
| Infertility | 57 | 2.3 |
| *Amenorrhea* | 0 | 0 |
| *Epididymitis* | 0 | 0 |
| *Fallopian tube damage* | 0 | 0 |
| *Ovulation disorder* | 0 | 0 |
| **Other** | | |

| Characteristic (n=4180) | No. | % |
|---|---|---|
| Aplastic anemia | 4 | 0.1 |
| Kidney disease | 9 | 0.2 |
| *End stage renal* | 1 | <0.1 |
| *Glomerulonephritis* | 1 | <0.1 |
| *Goodpastures syndrome* | 0 | 0 |
| *Nephrotic syndrome* | 3 | 0.1 |
| *Renal failure* | 5 | 0.1 |
| *Renal sclerosis* | 1 | <0.1 |
| Liver disease | 32 | 0.9 |
| *Biliary cirrhosis* | 1 | <0.1 |
| *Cirrhosis* | 8 | 0.2 |
| *Fatty liver* | 27 | 0.7 |
| *Hepatomegaly* | 3 | 0.1 |
| *Liver failure* | 1 | <0.1 |
| *Necrosis* | 0 | 0 |
| TCE-related skin disorder | 0 | 0 |

**Abbreviation**: TCE = trichloroethylene.

*Includes Marines who were not stationed at Camp Lejeune after March 1975 and their spouses.

†Race is missing for 155 people; total is greater than the number of participants because more than one race could be reported.

‡ 38 participants were deceased.

§1142 males and 2481 females.

‖sex was missing for 3 breast cancer cases.

**Table 20. Comparison of morbidity study results with an ATSDR assessment of the causal evidence of TCE and PCE and previous Camp Lejeune mortality studies**

| Disease | ATSDR assessment of causal evidence* | | Camp Lejeune Marines | | | | | Camp Lejeune Civilian Employees | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | TCE | PCE | Mortality study† HR and 95% CI | | | Morbidity study‡ OR and 95% CI | | Mortality study† HR and 95% CI | | | Morbidity study‡ OR and 95% CI |
| *Cancers* | | | CL vs CP§ | TCE | PCE | TCE | PCE | CL vs CP§ | TCE | PCE | TCE/PCE |
| Kidney | Sufficient | <equipoise | 1.4 (0.8, 2.2) | 1.5 (0.6, 3.6) | 1.6 (0.7, 3.9) | 1.6 (1.0, 2.5) | 2.0 (1.3, 3.1) | 1.9 (0.6, 6.3) | Not evaluated | | 42 (10, 169) |
| Bladder | <equipoise | Sufficient | 0.8 (0.3, 1.7) | 0.9 (0.2, 5.6) | 1.2 (0.3, 6.2) | 0.7 (0.4, 1.4) | 1.5 (1.0, 2.4) | 0.7 (0.1, 3.7) | Not evaluated | | 1.8 (0.5, 6.8) |
| Multiple myeloma | ≥equipoise | <equipoise | 1.7 (0.8, 3.7) | No cases | 0.6 (0.1, 3.1) | 0.5 (0.1, 2.4) | 1.4 (0.5, 3.4) | 1.8 (0.5, 7.6) | 0.6 (0.1, 3.2) | 0.5 (0.1, 2.9) | 2.7 (0.2, 43.8) |
| Leukemia | ≥equipoise | <equipoise | 1.1 (0.8, 1.6) | 1.8 (0.9, 3.9) | 1.4 (0.6, 3.0) | 0.3 (0.1, 0.7) | 1.0 (0.5, 1.8) | 1.6 (0.7, 3.8) | 1.4 (0.4, 5.3) | 1.3 (0.3, 5.1) | 1.6 (0.2, 15.3) |
| Non-Hodgkin lymphoma‖ | Sufficient | ≥equipoise | 0.8 (0.6, 1.2) | 1.2 (0.6, 2.3) | 1.1 (0.6, 2.3) | 0.9 (0.6, 1.5) | 1.1 (0.7, 1.8) | 0.83 (0.3, 2.7) | 0.3 (0.1, 2.1) | 0.3 (0.1, 2.1) | 1.9 (0.4, 8.1) |
| Liver | ≥equipoise | <equipoise | 1.4 (0.9, 2.2) | 0.9 (0.4, 2.0) | 0.8 (0.4, 1.9) | 1.2 (0.4, 3.5) | 1.3 (0.4, 3.8) | 0.6 (0.2, 2.5) | Not evaluated | | No cases |
| Pancreas | <equipoise | <equipoise | 1.4 (0.9, 2.0) | 0.6 (0.3, 1.2) | 0.6 (0.3, 1.3) | 0.3 (0.1, 1.2) | 1.4 (0.7, 2.8) | 0.5 (0.2, 1.2) | 0.5 (0.2, 1.6) | 0.5 (0.1, 1.5) | 12.5 (1.7, 90.5) |
| Prostate | <equipoise | <equipoise | 1.2 (0.6, 2.5) | 0.6 (0.2, 2.4) | 1.2 (0.4, 3.6) | 0.7 (0.5, 1.0) | 1.4 (1.1, 1.8) | 1.2 (0.5, 2.8) | 1.9 (0.4, 9.3) | 1.9 (0.4, 9.2) | 2.4 (1.3, 4.4) |
| Breast (female) | <equipoise | <equipoise | 0.9 (0.3, 2.5) | No cases | No cases | 1.3 (0.6, 2.6) | 1.5 (0.7, 3.1) | 1.2 (0.6, 2.5) | 1.2 (0.5, 2.8) | 1.3 (0.5, 3.1) | 5.1 (2.3, 11.1) |
| | | | | | | | | | | | |
| Esophagus | <equipoise | <equipoise | 1.4 (0.9, 2.4) | 0.7 (0.3, 1.8) | 0.4 (0.1, 1.3) | 1.2 (0.5, 2.9) | 1.6 (0.7, 3.5) | 0.6 (0.2, 2.2) | 2.4 (0.2, 24.6) | 2.1 (0.2, 21.9) | No cases |
| Rectum | <equipoise | <equipoise | 1.6 (0.8, 3.1) | 1.1 (0.4, 3.3) | 0.7 (0.2, 2.4) | 1.4 (0.6, 3.4) | 1.4 (0.6, 3.2) | 1.7 (0.4, 7.4) | 1.8 (0.2, 18.2) | Not evaluated | 7.1 (1.2, 42.9) |
| Brain | <equipoise | <equipoise | 0.9 (0.7, 1.3) | 0.9 (0.5, 1.9) | 1.1 (0.6, 2.1) | 0.9 (0.4, 1.9) | 1.5 (0.7, 2.9) | 0.7 (0.2, 2.0) | 1.0 (0.2, 4.9) | 0.9 (0.2, 4.5) | No cases |
| Pharynx¶ | N/A | N/A | 0.8 (0.5, 1.4) | 1.7 (0.6, 5.0) | 1.8 (0.6, 5.5) | 1.6 (0.7, 3.7) | 0.7 (0.2, 2.1) | 1.9 (0.3, 10.8) | 2.2 (0.2, 22.7) | 2.0 (0.2, 20.8) | Not evaluated |
| Colon | N/A | N/A | 1.0 (0.8, 1.4) | 1.0 (0.6, 1.9) | 0.8 (0.4, 1.6) | 0.9 (0.5, 1.5) | 1.5 (1.0, 2.2) | 1.0 (0.4, 2.4) | 0.6 (0.2, 2.0) | 0.6 (0.2, 1.9) | 5.5 (1.9, 16.1) |
| Larynx | N/A | N/A | 0.5 (0.2, 1.5) | Not evaluated | | 1.6 (0.5, 5.1) | 3.3 (1.4, 7.7) | Not evaluated | | | No cases |
| Lung | N/A | N/A | 1.2 (1.0, 1.4) | 1.2 (0.8, 1.7) | 1.1 (0.8, 1.6) | 0.7 (0.4, 1.2) | 1.2 (0.8, 1.8) | 1.3 (0.9, 1.8) | 0.7 (0.5, 1.2) | 1.0 (0.6, 1.6) | 1.1 (0.4, 3.2) |
| Soft Tissue | N/A | N/A | 1.4 (0.7, 2.6) | 0.4 (0.1, 1.7) | 0.2 (0.0, 1.4) | 1.4 (0.6, 3.6) | 2.2 (0.9, 5.0) | Not evaluated | | | No cases |
| Cervix | N/A | N/A | 1.3 (0.2, 7.3) | Not evaluated | Not evaluated | 1.1 (0.2, 4.9) | 0.5 (0.1, 4.2) | Not evaluated | | | No cases |
| *Non-cancer diseases* | | | | | | | | | | | |
| Kidney disease | ≥equipoise | ≥equipoise | 1.0 (0.6, 1.6) | 1.0 (0.4, 2.7) | 1.0 (0.4, 2.6) | 1.0 (0.7, 1.6) | 1.5 (1.0, 2.3) | 1.2 (0.4, 3.9) | 0.7 (0.2, 3.4) | 0.4 (0.1, 2.0) | 4.7 (1.2, 19.1) |
| Parkinson | ≥equipoise | <equipoise | Not evaluated | | | 0.3 (0.1, 1.1) | 1.3 (0.7, 2.5) | 3.1 (0.8, 12.9) | 2.5 (0.2, 30.8) | 2.7 (0.2, 33.3) | 2.0 (0.5, 7.9) |
| ALS | N/A | N/A | 0.8 (0.5, 1.5) | 1.9 (0.7, 5.8) | 2.0 (0.6, 6.0) | 1.7 (0.7, 4.3) | 2.6 (1.2, 5.7) | Not evaluated | | | No cases |

| Disease | ATSDR assessment of causal evidence* | | Camp Lejeune Marines | | | | | Camp Lejeune Civilian Employees | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | TCE | PCE | Mortality study† HR and 95% CI | | | Morbidity study‡ OR and 95% CI | | Mortality study† HR and 95% CI | | | Morbidity study‡ OR and 95% CI |
| | | | CL vs CP§ | TCE | PCE | TCE | PCE | CL vs CP§ | TCE | PCE | TCE/PCE |
| Scleroderma | ≥equipoise | <equipoise | Not evaluated | | | 0.8 (0.1, 6.9) | 0.8 (0.1, 6.9) | Not evaluated | | | No cases |
| Lupus | N/A | N/A | Not evaluated | | | 0.9 (0.4, 2.2) | 1.0 (0.4, 2.4) | Not evaluated | | | 4.7 (0.3, 76.1) |
| Multiple Sclerosis | N/A | N/A | 1.2 (0.5, 2.9) | Not evaluated | Not evaluated | 1.5 (0.8, 2.6) | 0.5 (0.2, 1.2) | Not evaluated | | | 1.6 (0.2, 15.3) |
| Male infertility | N/A | N/A | Not evaluated | | | 0.9 (0.5, 1.7) | 0.7 (0.4, 1.4) | Not evaluated | | | Not evaluated |
| Female infertility | N/A | N/A | Not evaluated | | | 1.1 (0.5, 2.2) | 1.1 (0.5, 2.2) | Not evaluated | | | 0.03 (0.0, 2.4) |
| Endometriosis | N/A | N/A | Not evaluated | | | 1.3 (0.6, 2.7) | 1.3 (0.6, 2.7) | Not evaluated | | | 0.4 (0.1, 2.9) |
| Aplastic Anemia | N/A | N/A | Not evaluated | | | 0.5 (0.1, 3.5) | 1.7 (0.5, 5.6) | Not evaluated | | | Not evaluated |
| Liver disease | N/A | N/A | 0.9 (0.7, 1.1) | 1.2 (0.8, 1.7) | 1.1 (0.7, 1.6) | 1.2 (0.8, 1.6) | 1.3 (0.9, 1.8) | 0.9 (0.3, 2.3) | 0.5 (0.1, 2.3) | 0.5 (0.1, 2.1) | 0.5 (0.1, 3.7) |

**Abbreviations**: ATSDR = Agency for Toxic Substances and Disease Registry; TCE = trichloroethylene; PCE = tetrachloroethylene; HR = hazard ration; OR = odds ratio; CI = confidence interval; CL = Camp Lejeune; CP = Camp Pendleton; N/A = not available; ALS = amyotrophic lateral sclerosis.

*ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases (ATSDR 2017).

† Mortality hazard ratio results for Marines are from Table S1, Additional File 2, high cumulative exposure (internal analyses) (Bove et al. 2014a) and for civilian employees are from Table S2b, "≥ median cumulative exposure (internal analyses) (Bove et al. 2014b).

‡ Morbidity study odds ratio results are for the internal analyses "high cumulative exposure."

§ CL vs CP: The hazard ratio for the comparison between Camp Lejeune and Camp Pendleton.

ǀ The morbidity study evaluated all lymphomas including non-Hodgkin lymphoma.

¶ Results for the mortality studies are for oral cancers that include cancers of the oral cavity as well as pharynx.

Notes:

"Equipoise" is defined as evidence that is at least as likely as not.

N/A: Causal evidence not assessed by ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases (ATSDR 2017).

The diseases not evaluated in the mortality studies were due to sparse data or were conditions that do not lead to death.

**Table 21. Key results from the internal analyses of high cumulative exposure in the morbidity study**

| Disease | Camp Lejeune Marines | | | | | | Camp Lejeune Civilian Employees | | | | Supported by ATSDR assessment of causal evidence† | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OR ≥ 1.5 | | Monotonic exposure-response relationship | | Supported by previous Camp Lejeune mortality studies* | | OR ≥ 1.5 | Monotonic exposure-response relationship | Supported by previous Camp Lejeune mortality studies* | | | |
| | TCE | PCE | TCE | PCE | TCE | PCE | TCE/PCE | TCE/PCE | TCE | PCE | TCE | PCE |
| Kidney cancer | x | x | x | x | x | x | x | x | Not evaluated | | x | |
| Bladder cancer | | x | | | | | x | | Not evaluated | | | x |
| Kidney disease | | x | | x | | | x | x | | | x | x |

**Abbreviations**: ATSDR = Agency for Toxic Substances and Disease Registry; TCE = trichloroethylene; PCE = tetrachloroethylene; OR = odds ratio; x is used to denote that the criteria is present.

-- could not be calculated because of zero cells.

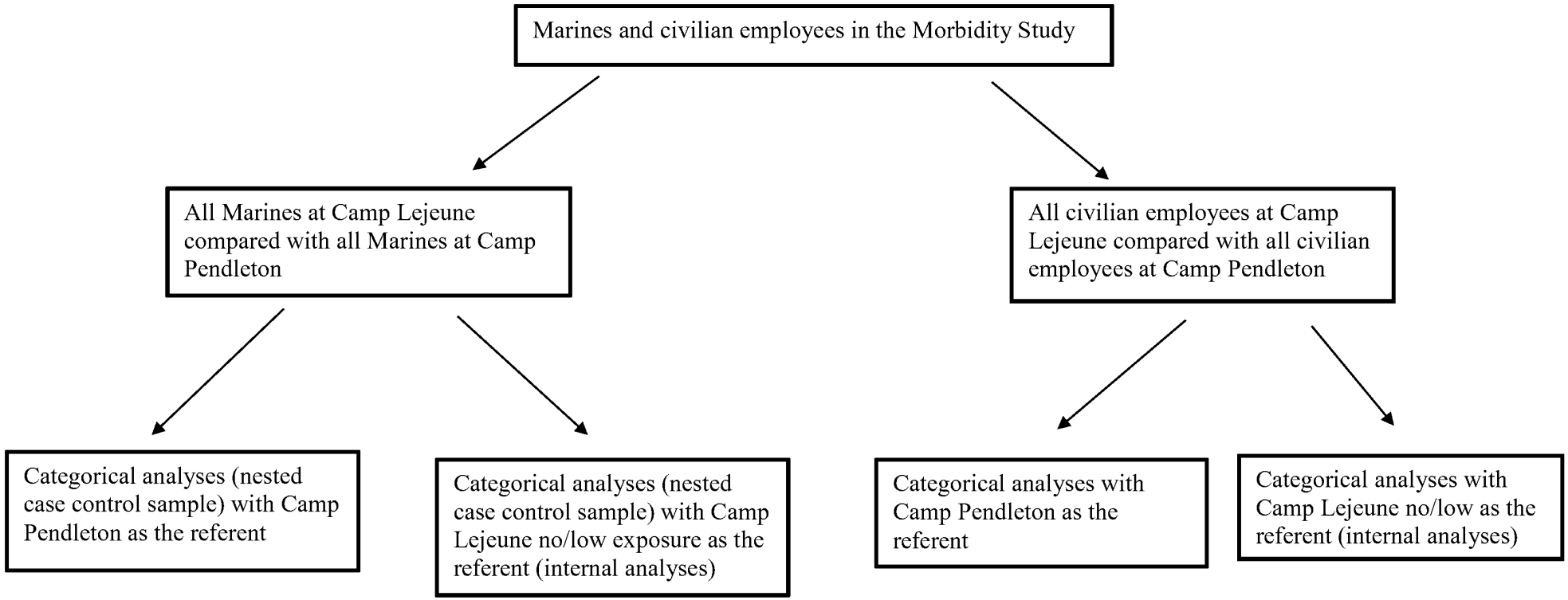
*Mortality hazard ratio results ≥ 1.5 from Table S1, Additional File 2, high cumulative exposure (internal analyses of Marines) (Bove et al. 2014a) and from Table S2b, "≥ median cumulative exposure (internal analyses for civilian employees) (Bove et al. 2014b).

†ATSDR Assessment of the Evidence for the Drinking Water Contaminants at Camp Lejeune and Specific Cancers and Other Diseases (ATSDR 2017) concluded that the evidence was at least equipoise and above (at least as likely as not).

Note: The diseases not evaluated in the mortality studies were due to sparse data or were conditions that do not lead to death.

**FIGURE 1.**

Types of analyses conducted in the morbidity study



# APPENDIX. RESULTS OF SURVEYS SENT TO REGISTRANTS IN THE U.S. MARINE CORPS NOTIFICATION DATABASE

**Introduction**

This report focuses on survey responses from those who were stationed, employed, or lived at Camp Lejeune in or before 1987 who registered with the United States Marine Corps (USMC) Notification Database to receive updated information about Camp Lejeune drinking water contamination (USMC 2016). These individuals were not part of the morbidity study because they were not included in the Defense Manpower Data Center (DMDC) personnel database or the previous 1999-2002 ATSDR survey of children born at Camp Lejeune.

**Methods**

Surveys were sent in 2011 and 2012 to 110,239 people who registered with the USMC by June 30, 2011 as having lived or worked at Camp Lejeune in 1987 or before. Using the same survey as in the morbidity study, respondents were asked to recount dates and locations of residence on base at Camp Lejeune; cancer and non-cancer diseases diagnosed by a health provider since the individual first lived, was stationed, or worked at Camp Lejeune; pregnancy outcomes while on base; occupational exposures; and Vietnam service; as well as basic demographic information (education, race, smoking, drinking habits, etc.). Self-reported data on the health outcomes and residences at Camp Lejeune were not verified in this analysis.

Data from surveys returned by July 31, 2013 were analyzed to determine demographics and prevalence and frequency of cancers (bladder, brain, breast, cervical, colon, esophageal, kidney, laryngeal, leukemia, liver, lung, lymphoma, multiple myeloma, pancreatic, pharyngeal, prostate, rectal, soft tissue) and other health outcomes (amyotrophic lateral sclerosis [ALS], aplastic anemia, endometriosis, infertility, kidney

disease, liver disease, lupus, multiple sclerosis [MS], Parkinson's disease, scleroderma, and skin disorders). These diseases were selected based on an extensive literature review of occupational and drinking water studies involving solvent exposure (Bove and Ruckart 2008). Some respondents did not provide their sex. Information for those with missing sex was recoded to male for 269 respondents who reported being stationed at Camp Lejeune before 1965 and 82 respondents who reported male cancers and diseases and to female for 29 respondents who reported female cancers and diseases.

**Results**

A total of 24,800 (22.5%) surveys were returned; 287 (1.2%) were excluded because the respondent reported only having been stationed at bases other than Camp Lejeune (n= 190, 0.77%) or the respondent reported being stationed at Camp Lejeune after 1987 (n= 98, 0.40%). Therefore, 24,513 surveys were retained for analysis.

Demographics

Among respondents, 18,705 (76.3%), were former active duty Marines and 3,478 (14.2%) were dependents of Marines. Only 67 (0.3%) were civilian workers (Table A1). Affiliation with Camp Lejeune was not reported by 2,263 (9.2%) respondents. The majority of respondents reported being white (n= 20,205, 82.4%) followed by African American (n= 2,412, 9.8%) and multiracial (n= 1,490, 6.1%). Because of limited data, the remaining 406 (1.7%) respondents were collectively categorized as "other" race.

Of the 24,030 respondents with information on sex, the majority were male (n=20,351, 84.7%); however, the majority of both civilian workers (n= 35, 54.7%) and dependents (n= 2,544, 74.1%) were female. Almost all respondents that reported education earned at least a high school degree (n= 22,849, 97.2%); slightly less than half

of those respondents reported receiving an associate/technical degree or having some college education (n= 10,422, 45.6%), and a third reported receiving a college or advanced degree (n= 7,632, 33.4%). Dependents and respondents who did not report affiliation were most likely to have received a college or advanced degree (n= 1,328, 38.6% of all dependents and n= 723, 41.6% of all respondents with unreported affiliations who reported education level).

Respondents were asked if they worked with hazardous substances starting with when they were first stationed, lived or employed at Camp Lejeune up through their present job. About a quarter of Marines reported having worked with pesticides, radiation, or various other chemicals (22.5%, 23.7%, and 25.2%, respectively) and a third of Marines reported having worked with solvents (n= 6,704, 35.8%) since they were first stationed at Camp Lejeune. Approximately 25% of civilian employees reported having worked with pesticides (25.4%), solvents (26.9%), or other chemicals (26.9%).

About two thirds of respondents (n= 15,522, 63.3%) reported ever having been a smoker. However, smoking status varied by affiliation; nearly 70% of Marines reporting having ever smoked compared with less than half of dependents. Nearly all respondents (n= 22,749, 92.8%) reported being current drinkers. Of the 10,323 respondents who reported how much alcohol they drank, 25.6% reported having 1-3 drinks per month, 22.0% reported drinking daily, 20.7% reported drinking 2-4 times per week, 17.4% reported drinking less than 1 drink per month, and 14.3% reported having 1 drink per week. Almost a third of the dependents reported drinking daily.

Cancer occurrence

Table A2a shows the prevalence of the cancers by affiliation. Overall, 2,586 (10.5%) respondents reported a total of 3,404 specific cancers of interest. The majority of cancers were reported by Marines (n= 2,784, 81.8%); only 12 cancers were reported by civilian workers. For all affiliations, the most prevalent cancers were prostate (n= 987, 4.8%), female breast (n=176, 4.7%), cervical (n= 90, 2.4%), colon (n= 294, 1.2%), lung (n= 263, 1.1%), bladder (n= 234, 1.0%), and kidney (n= 218, 0.9%) (Table A2a). No cases of colon or kidney cancer were reported by civilian workers.

Table A2b shows the distribution of the cancers by affiliation. Higher percentages of cancers of the prostate and colon and multiple myeloma were reported by Marines. Dependents most often reported female breast cancer (n= 117, 31.3%) followed by cervical (13.6%) and colon (8.0%) cancers. Similar percentages of male breast cancer were reported by Marines, dependents, and respondents with unknown affiliation (0.2%, 0.6%, and 0.2%, respectively). However, no civilian workers reported any cases of male breast cancer .

Male respondents most commonly reported prostate (33.8%), colon (9.0%), and lung (8.1%) cancers. Female respondents most commonly reported breast (36.7%), cervical (18.8%), and colon (6.9%) cancers (Table A3). Reports of female breast cancer were higher than reports of male breast cancer (36.7% vs. 1.5%). Cancers of the respiratory and urinary systems were more often reported by males. Liver cancer was more likely to be reported by African Americans (8.4%) and multiracial respondents (9.9%) than White (3.1%) and “other” (3.2%) respondents (Table A4). Hematopoietic cancers were less likely to be reported by African Americans. Female breast cancers was

more commonly reported among white respondents. Male breast cancer was reported almost entirely by white respondents (97.8% of all reported male breast cancers).

Non-cancer disease occurrence

Across affiliations, 13,200 non-cancer diseases of interest were reported by 9,632 (39.3%) respondents which is nearly four times the total number of cancers reported. Table A5a shows the prevalence of the non-cancer diseases by affiliation. The most prevalent non-cancer diseases reported across all affiliations combined were skin disorders (n= 5,921, 24.2%), endometriosis (n= 641, 17.4%), female infertility (n= 373, 10.1%), kidney disease (n= 1,847, 7.5%), and liver disease (n= 1,633, 6.7%). Table A5b shows the distribution of the non-cancer diseases by affiliation. Marines (n= 4,878, 48.1%) and respondents of unknown affiliation (n= 331, 39.8%) were most likely to report skin disorders. Higher percentages of endometriosis, female infertility, and kidney disease were reported by civilian workers. Dependents were twice as likely to report MS (2.1% vs. 1.0%) and three times more likely to report lupus (4.4 % vs. 1.3%) than were Marines.

Nearly half of non-cancer diseases reported by males were skin-disorders (Table A6), which was approximately 20% higher than skin disorders reported by females. After skin disorders, endometriosis was the most common disease reported by females (25.3%); whereas, for males, kidney disease was the second most common disease reported (14.9%). Infertility was reported similarly by male and female respondents (12.8% and 14.7%, respectively). In male respondents, infertility was most often reported as being the result of low sperm count (53.8%). Scleroderma reports were higher among respondents whose race was categorized as “other” than among the other

races (Table A7). Endometriosis was more commonly reported by white respondents. A similar percentage of kidney disease was reported by African American, white and multiracial respondents, and least by respondents whose race was categorized as "other."

Pregnancy outcome

Female respondents were asked to report pregnancy outcomes that occurred during their time living or working on-base. Dependents reported the majority of pregnancy outcomes (n= 1,104, 64.8%) followed by Marines (n= 314, 18.4%) (Table A8). Of the 1,704 pregnancy outcomes reported, most were reported as live single births (80.9%) followed by miscarriages (16.0%). Marines reported higher rates of miscarriages than all other affiliations (n= 67, 21.3% of all reported pregnancy outcomes in Marines).

**Discussion and Conclusion**

This analysis describes the self-reported health conditions of 24,513 Marines, dependents, civilian employees, and registrants with unknown affiliations who registered with the USMC notification database and completed a health survey. Overall, most survey respondents were Marines, followed by dependents, respondents with unknown affiliation, and civilian workers. Most respondents were white males, followed by white females and African American males. In total, 3,404 cancers of interest were reported by 2,586 respondents and 13,200 non-cancer diseases of interest were reported by 9,632 respondents across all affiliations.

Overall, the most prevalent cancers across all affiliations were prostate, female breast, cervical, colon and lung. The least prevalent were laryngeal, pancreatic and male breast cancers. The most frequently reported cancers among Marines and male

respondents were prostate, colon, and lung cancers. The most frequently reported cancers among dependents and female respondents were female breast, cervical, and colon cancers. Respondents with an unreported affiliation most often reported prostate, kidney, and lung cancers.

Respondents were almost four times more likely to report non-cancer diseases It than cancers of interest. The most prevalent non-cancer diseases reported by all affiliations were skin disorders, endometriosis, female infertility, kidney disease, and liver disease. Autoimmune and nervous system disorders were the least prevalent.

Most reported pregnancies outcomes were live single births. The next most reported outcome was miscarriages. Dependents reported the majority of overall pregnancy outcomes. Marines were more likely to report miscarriages than any other affiliation with more than one fifth of all pregnancy outcomes reported as miscarriages. In conclusion, the data presented in this report provide a descriptive summary of the information reported by the survey respondents who were stationed, employed, or lived at Camp Lejeune during the period of drinking water contamination. It should be noted that registrants with health problems were probably more likely to complete a health survey than registrants without health problems.

**References**

Bove FJ, Ruckart PZ. An Assessment of the Feasibility of Conducting Future Epidemiological Studies at USMC Base Camp Lejeune. 2008. http://www.atsdr.cdc.gov/sites/lejeune/docs/feasibility_assessment_Lejeune.pdf

United States Marine Corps, 2016. Camp Lejeune Historic Drinking Water Notification Database. Washington, DC [accessed 2016 August 26]. Available from: https://clnr.hqi.usmc.mil/clwater/

## APPENDIX TABLES

**Table A1. Demographics of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey***

| | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | Civilian worker | | Dependent | | Not reported | | Total | |
| **Demographics** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| **Race** | | | | | | | | | | |
| White | 15614 | 83.5 | 45 | 67.2 | 3011 | 86.6 | 1535 | 67.8 | 20205 | 82.4 |
| African American | 1957 | 10.5 | 16 | 23.9 | 291 | 8.4 | 148 | 6.5 | 2412 | 9.8 |
| Multiracial | 824 | 4.4 | 4 | 6.0 | 109 | 3.1 | 553 | 24.4 | 1490 | 6.1 |
| Other | 310 | 1.7 | 2 | 3.0 | 67 | 1.9 | 27 | 1.2 | 406 | 1.7 |
| **Sex** | | | | | | | | | | |
| Male | 17966 | 96.0 | 29 | 43.3 | 888 | 25.5 | 1468 | 64.9 | 20351 | 83.0 |
| Female | 559 | 3.0 | 35 | 52.2 | 2544 | 73.1 | 541 | 23.9 | 3679 | 15.0 |
| Missing | 180 | 1.0 | 3 | 4.5 | 46 | 1.3 | 254 | 11.2 | 483 | 2.0 |
| **Education** | | | | | | | | | | |
| Not a high school graduate | 519 | 2.8 | 2 | 3.0 | 101 | 2.9 | 46 | 2.0 | 668 | 2.7 |
| High school | 3937 | 21.0 | 16 | 23.9 | 570 | 16.4 | 272 | 12.0 | 4795 | 19.6 |
| Some college | 8263 | 44.2 | 27 | 40.3 | 1437 | 41.3 | 695 | 30.7 | 10422 | 42.5 |
| Bachelor's degree or higher | 5563 | 29.7 | 18 | 26.9 | 1328 | 38.2 | 723 | 31.9 | 7632 | 31.1 |
| Missing | 423 | 2.3 | 4 | 6.0 | 42 | 1.2 | 527 | 23.3 | 996 | 4.1 |
| **Vietnam service** | | | | | | | | | | |
| 1965-1968 | 1204 | 6.4 | 0 | 0.0 | 10 | 0.3 | 68 | 3.0 | 1282 | 5.2 |
| 1969-1971 | 2034 | 10.9 | 2 | 3.0 | 14 | 0.4 | 99 | 4.4 | 2149 | 8.8 |
| No service reported | 15467 | 82.7 | 65 | 97.0 | 3454 | 99.3 | 2096 | 92.6 | 21082 | 86.0 |
| **Worked with pesticides** | | | | | | | | | | |
| Yes | 4209 | 22.5 | 17 | 25.4 | 242 | 7.0 | 271 | 12.0 | 4739 | 19.3 |
| No | 14496 | 77.5 | 50 | 74.6 | 3236 | 93.0 | 1992 | 88.0 | 19774 | 80.7 |
| **Worked with radiation** | | | | | | | | | | |
| Yes | 4440 | 23.7 | 8 | 11.9 | 386 | 11.1 | 371 | 16.4 | 5205 | 21.2 |
| No | 14265 | 76.3 | 59 | 88.1 | 3092 | 88.9 | 1892 | 83.6 | 19308 | 78.8 |
| **Worked with metals** | | | | | | | | | | |
| Yes | 3014 | 16.1 | 11 | 16.4 | 150 | 4.3 | 225 | 9.9 | 3400 | 13.9 |
| No | 15691 | 83.9 | 56 | 83.6 | 3328 | 95.7 | 2038 | 90.1 | 21113 | 86.1 |
| **Worked with solvents** | | | | | | | | | | |
| Yes | 6704 | 35.8 | 18 | 26.9 | 367 | 10.6 | 406 | 17.9 | 7495 | 30.6 |
| No | 12001 | 64.2 | 49 | 73.1 | 3111 | 89.4 | 1857 | 82.1 | 17018 | 69.4 |
| **Worked with other chemicals** | | | | | | | | | | |

| | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | Civilian worker | | Dependent | | Not reported | | Total | |
| **Demographics** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| Yes | 4722 | 25.2 | 18 | 26.9 | 288 | 8.3 | 343 | 15.2 | 5371 | 21.9 |
| No | 13983 | 74.8 | 49 | 73.1 | 3190 | 91.7 | 1920 | 84.8 | 19142 | 78.1 |
| **Ever smoked cigarettes** | | | | | | | | | | |
| Yes | 12920 | 69.1 | 37 | 55.2 | 1606 | 46.2 | 959 | 42.4 | 15522 | 63.3 |
| No | 5785 | 30.9 | 30 | 44.8 | 1872 | 53.8 | 1304 | 57.6 | 8991 | 36.7 |
| **Current alcohol consumption** | | | | | | | | | | |
| Not a current drinker | 829 | 4.4 | 7 | 10.4 | 329 | 9.5 | 599 | 26.5 | 1764 | 7.2 |
| Current Drinker | 17876 | 95.6 | 60 | 89.6 | 3149 | 90.5 | 1664 | 73.5 | 22749 | 92.8 |
| *<1 drink per month* | *1498* | *18.7* | *7* | *25.9* | *153* | *10.0* | *136* | *17.9* | *1794* | *17.4* |
| *1-3 drinks per month* | *2142* | *26.7* | *6* | *22.2* | *329* | *21.5* | *169* | *22.3* | *2646* | *25.6* |
| *1 drink per week* | *1158* | *14.5* | *1* | *3.7* | *212* | *13.9* | *108* | *14.2* | *1479* | *14.3* |
| *2-4 drinks per week* | *1632* | *20.4* | *6* | *22.2* | *341* | *22.3* | *154* | *20.3* | *2133* | *20.7* |
| *Daily* | *1579* | *19.7* | *7* | *25.9* | *494* | *32.3* | *191* | *25.2* | *2271* | *22.0* |
| *Missing* | *9867* | *55.2* | *33* | *55.0* | *1,620* | *51.4* | *906* | *54.4* | *12426* | *54.6* |
| **Total** | **18705** | **76.3** | **67** | **0.3** | **3478** | **14.2** | **2263** | **9.2** | **24513** | **100.0** |

*These individuals were excluded from the morbidity study analyses.

**Table A2a. Prevalence of reported cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by affiliation**

| | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine (n=18705) | | Civilian worker (n= 67) | | Dependent (n= 3478) | | Not reported (n= 2263) | | Total (n= 24513) | |
| **Cancers** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| **Digestive organs** | | | | | | | | | | |
| Colon | 247 | 1.3 | 0 | 0.0 | 30 | 0.9 | 17 | 0.8 | 294 | 1.2 |
| Esophageal | 68 | 0.4 | 1 | 1.5 | 5 | 0.1 | 4 | 0.2 | 78 | 0.3 |
| Liver | 105 | 0.6 | 0 | 0.0 | 11 | 0.3 | 16 | 0.7 | 132 | 0.5 |
| Pancreatic | 42 | 0.2 | 0 | 0.0 | 3 | 0.1 | 5 | 0.2 | 50 | 0.2 |
| Rectal | 58 | 0.3 | 1 | 1.5 | 5 | 0.1 | 1 | < 0.1 | 65 | 0.3 |
| **Hematopoietic** | | | | | | | | | | |
| Leukemia | 104 | 0.6 | 0 | 0.0 | 19 | 0.5 | 9 | 0.4 | 132 | 0.5 |
| Lymphoma | 146 | 0.8 | 1 | 1.5 | 28 | 0.8 | 14 | 0.6 | 189 | 0.8 |
| Multiple myeloma | 97 | 0.5 | 0 | 0.0 | 9 | 0.3 | 5 | 0.2 | 111 | 0.5 |
| **Respiratory system** | | | | | | | | | | |
| Laryngeal | 34 | 0.2 | 0 | 0.0 | 1 | 0.0 | 3 | 0.1 | 38 | 0.2 |
| Lung | 219 | 1.2 | 1 | 1.5 | 20 | 0.6 | 23 | 1.0 | 263 | 1.1 |
| **Sex-specific** | | | | | | | | | | |
| Male breast | 37 | 0.2 | 0 | 0.0 | 5 | 0.6 | 3 | 0.2 | 45 | 0.2 |
| Female breast | 39 | 7.0 | 3 | 8.6 | 117 | 4.6 | 17 | 3.1 | 176 | 4.7 |
| Cervical | 23 | 4.1 | 0 | 0.0 | 51 | 2.0 | 16 | 3.0 | 90 | 2.4 |
| Prostate | 924 | 5.1 | 1 | 3.4 | 13 | 1.5 | 49 | 3.3 | 987 | 4.8 |
| **Urinary system** | | | | | | | | | | |
| Bladder | 214 | 1.1 | 2 | 3.0 | 10 | 0.3 | 8 | 0.4 | 234 | 1.0 |
| Kidney | 177 | 0.9 | 0 | 0.0 | 17 | 0.5 | 24 | 1.1 | 218 | 0.9 |
| **Other** | | | | | | | | | | |
| Brain | 68 | 0.4 | 1 | 1.5 | 14 | 0.4 | 8 | 0.4 | 91 | 0.4 |
| Pharyngeal | 85 | 0.5 | 1 | 1.5 | 6 | 0.2 | 3 | 0.1 | 95 | 0.4 |
| Soft tissue | 97 | 0.5 | 0 | 0.0 | 10 | 0.3 | 9 | 0.4 | 116 | 0.5 |
| **Total** | **2784** | - | **12** | - | **374** | - | **234** | - | **3404** | - |

Note: Marines: male = 17,966, female = 559, and not reported = 180; Civilian Workers: male = 29, female = 35, and not reported = 3; Dependents: male = 888, female = 2,544, and not reported = 46; Unreported affiliation: male = 1,468, female = 541, and not reported = 254.

**Table A2b. Frequency of reported cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by affiliation**

| | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | Civilian worker | | Dependent | | Not reported | | Total | |
| **Cancers** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| **Digestive organs** | | | | | | | | | | |
| Colon | 247 | 8.9 | 0 | 0.0 | 30 | 8.0 | 17 | 7.3 | 294 | 8.6 |
| Esophageal | 68 | 2.4 | 1 | 8.3 | 5 | 1.3 | 4 | 1.7 | 78 | 2.3 |
| Liver | 105 | 3.8 | 0 | 0.0 | 11 | 2.9 | 16 | 6.8 | 132 | 3.9 |
| Pancreatic | 42 | 1.5 | 0 | 0.0 | 3 | 0.8 | 5 | 2.1 | 50 | 1.5 |
| Rectal | 58 | 2.1 | 1 | 8.3 | 5 | 1.3 | 1 | 0.4 | 65 | 1.9 |
| **Hematopoietic** | | | | | | | | | | |
| Leukemia | 104 | 3.7 | 0 | 0.0 | 19 | 5.1 | 9 | 3.8 | 132 | 3.9 |
| Lymphoma | 146 | 5.2 | 1 | 8.3 | 28 | 7.5 | 14 | 6.0 | 189 | 5.6 |
| Multiple myeloma | 97 | 3.5 | 0 | 0.0 | 9 | 2.4 | 5 | 2.1 | 111 | 3.3 |
| **Respiratory system** | | | | | | | | | | |
| Laryngeal | 34 | 1.2 | 0 | 0.0 | 1 | 0.3 | 3 | 1.3 | 38 | 1.1 |
| Lung | 219 | 7.9 | 1 | 8.3 | 20 | 5.3 | 23 | 9.8 | 263 | 7.7 |
| **Sex-specific** | | | | | | | | | | |
| Male breast | 37 | 1.3 | 0 | 0.0 | 5 | 1.3 | 3 | 1.3 | 45 | 1.3 |
| Female breast | 39 | 1.4 | 3 | 25.0 | 117 | 31.3 | 17 | 7.3 | 176 | 5.2 |
| Cervical | 23 | 0.8 | 0 | 0.0 | 51 | 13.6 | 16 | 6.8 | 90 | 2.6 |
| Prostate | 924 | 33.2 | 1 | 8.3 | 13 | 3.5 | 49 | 20.9 | 987 | 29.0 |
| **Urinary system** | | | | | | | | | | |
| Bladder | 214 | 7.7 | 2 | 16.7 | 10 | 2.7 | 8 | 3.4 | 234 | 6.9 |
| Kidney | 177 | 6.4 | 0 | 0.0 | 17 | 4.5 | 24 | 10.3 | 218 | 6.4 |
| **Other** | | | | | | | | | | |
| Brain | 68 | 2.4 | 1 | 8.3 | 14 | 3.7 | 8 | 3.4 | 91 | 2.7 |
| Pharyngeal | 85 | 3.1 | 1 | 8.3 | 6 | 1.6 | 3 | 1.3 | 95 | 2.8 |
| Soft tissue | 97 | 3.5 | 0 | 0.0 | 10 | 2.7 | 9 | 3.8 | 116 | 3.4 |
| **Total** | **2784** | **81.8** | **12** | **<0.01** | **374** | **11.0** | **234** | **6.9** | **3404** | **100.0** |

**Table A3. Frequency of reported cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by sex**

| | Sex | | | | | |
|---|---|---|---|---|---|---|
| | Male | | Female | | Not reported | |
| **Cancers** | **No.** | **%** | **No.** | **%** | **No.** | **%** |
| **Digestive organs** | | | | | | |
| Colon | 261 | 9.0 | 33 | 6.9 | 0 | 0.0 |
| Esophageal | 73 | 2.5 | 5 | 1.0 | 0 | 0.0 |
| Liver | 116 | 4.0 | 16 | 3.3 | 0 | 0.0 |
| Pancreatic | 45 | 1.5 | 5 | 1.0 | 0 | 0.0 |
| Rectal | 56 | 1.9 | 9 | 1.9 | 0 | 0.0 |
| **Hematopoietic** | | | | | | |
| Leukemia | 114 | 3.9 | 16 | 3.3 | 2 | 22.2 |
| Lymphoma | 160 | 5.5 | 28 | 5.8 | 1 | 11.1 |
| Multiple myeloma | 99 | 3.4 | 10 | 2.1 | 2 | 22.2 |
| **Respiratory system** | | | | | | |
| Laryngeal | 35 | 1.2 | 3 | 0.6 | 0 | 0.0 |
| Lung | 235 | 8.1 | 26 | 5.4 | 2 | 22.2 |
| **Sex-specific** | | | | | | |
| Breast | 45 | 1.5 | 176 | 36.7 | - | - |
| Cervical | - | - | 90 | 18.8 | - | - |
| Prostate | 987 | 33.8 | - | - | - | - |
| **Urinary system** | | | | | | |
| Bladder | 222 | 7.6 | 12 | 2.5 | 0 | 0.0 |
| Kidney | 197 | 6.8 | 20 | 4.2 | 1 | 11.1 |
| **Other** | | | | | | |
| Brain | 79 | 2.7 | 12 | 2.5 | 0 | 0.0 |
| Pharyngeal | 85 | 2.9 | 9 | 1.9 | 1 | 11.1 |
| Soft tissue | 107 | 3.7 | 9 | 1.9 | 0 | 0.0 |
| **Total** | **2916** | **85.7** | **479** | **14.1** | **9** | **0.3** |

**Table A4. Frequency of reported cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by race**

| | Race | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | African American | | White | | Other | | Multiracial | |
| **Cancers** | No. | % | No. | % | No. | % | No. | % |
| **Digestive organs** | | | | | | | | |
| Colon | 27 | 8.8 | 244 | 8.6 | 8 | 8.6 | 15 | 9.3 |
| Esophageal | 6 | 1.9 | 66 | 2.3 | 3 | 3.2 | 3 | 1.9 |
| Liver | 26 | 8.4 | 87 | 3.1 | 3 | 3.2 | 16 | 9.9 |
| Pancreas | 6 | 1.9 | 41 | 1.4 | 1 | 1.1 | 2 | 1.2 |
| Rectal | 8 | 2.6 | 50 | 1.8 | 5 | 5.4 | 2 | 1.2 |
| **Hematopoietic** | | | | | | | | |
| Leukemia | 6 | 1.9 | 117 | 4.1 | 2 | 2.2 | 7 | 4.3 |
| Lymphoma | 15 | 4.9 | 164 | 5.8 | 4 | 4.3 | 6 | 3.7 |
| Multiple myeloma | 4 | 1.3 | 98 | 3.4 | 6 | 6.5 | 3 | 1.9 |
| **Respiratory system** | | | | | | | | |
| Laryngeal | 3 | 1.0 | 33 | 1.2 | 2 | 2.2 | 0 | 0.0 |
| Lung | 23 | 7.5 | 213 | 7.5 | 9 | 9.7 | 18 | 11.1 |
| **Sex-specific** | | | | | | | | |
| Male breast | 0 | 0.0 | 44 | 1.5 | 1 | 1.1 | 0 | 0.0 |
| Female breast | 10 | 3.2 | 152 | 5.4 | 10 | 10.8 | 4 | 2.5 |
| Cervical | 5 | 1.6 | 75 | 2.6 | 4 | 4.3 | 6 | 3.7 |
| Prostate | 102 | 33.1 | 833 | 29.3 | 12 | 12.9 | 40 | 24.7 |
| **Urinary system** | | | | | | | | |
| Bladder | 16 | 5.2 | 204 | 7.2 | 3 | 3.2 | 11 | 6.8 |
| Kidney | 27 | 8.8 | 175 | 6.2 | 5 | 5.4 | 11 | 6.8 |
| **Other** | | | | | | | | |
| Brain | 6 | 1.9 | 76 | 2.7 | 5 | 5.4 | 4 | 2.5 |
| Pharyngeal | 9 | 2.9 | 75 | 2.6 | 6 | 6.5 | 5 | 3.1 |
| Soft tissue | 9 | 2.9 | 94 | 3.3 | 4 | 4.3 | 9 | 5.6 |
| **Total** | **308** | **9.0** | **2841** | **83.5** | **93** | **2.7** | **162** | **4.8** |

**Table A5a. Prevalence of reported non-cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by affiliation**

| Non-cancer diseases | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine (n= 18705) | | Civilian worker (n= 67) | | Dependent (n= 3478) | | Not reported (n= 2263) | | Total (n= 24513) | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| **Autoimmune** | | | | | | | | | | |
| Lupus | 134 | 0.7 | 1 | 1.5 | 97 | 2.8 | 17 | 0.8 | 249 | 1.0 |
| Scleroderma | 140 | 0.7 | 1 | 1.5 | 30 | 0.9 | 12 | 0.5 | 183 | 0.7 |
| **Nervous system** | | | | | | | | | | |
| ALS | 175 | 0.9 | 0 | 0.0 | 21 | 0.6 | 25 | 1.1 | 221 | 0.9 |
| MS | 102 | 0.5 | 1 | 1.5 | 45 | 1.3 | 7 | 0.3 | 155 | 0.6 |
| Parkinson disease | 239 | 1.3 | 2 | 3.0 | 27 | 0.8 | 17 | 0.8 | 285 | 1.2 |
| **Male reproductive organs** | | | | | | | | | | |
| Infertility | 1218 | 6.8 | 4 | 13.8 | 58 | 6.5 | 64 | 4.4 | 1344 | 6.6 |
| *Abnormal sperm* | *162* | *13.3* | *0* | *0.0* | *8* | *13.8* | *14* | *21.9* | 184 | *13.7* |
| *Low sperm count* | *645* | *53.0* | *1* | *25.0* | *37* | *63.8* | *39* | *60.9* | 722 | *53.7* |
| **Female reproductive organs** | | | | | | | | | | |
| Endometriosis | 92 | 16.5 | 7 | 20.0 | 459 | 18.0 | 83 | 15.3 | 641 | 17.4 |
| Infertility | 50 | 8.9 | 5 | 14.3 | 265 | 10.4 | 53 | 9.8 | 373 | 10.1 |
| *Fallopian tube damage* | *21* | *42.0* | *3* | *60.0* | *54* | *20.4* | *14* | *26.4* | 92 | *24.7* |
| **Other** | | | | | | | | | | |
| Aplastic anemia | 273 | 1.5 | 0 | 0.0 | 55 | 1.6 | 20 | 0.9 | 348 | 1.4 |
| Kidney disease | 1507 | 8.1 | 7 | 10.4 | 223 | 6.4 | 110 | 4.9 | 1847 | 7.5 |
| Liver disease | 1327 | 7.1 | 4 | 6.0 | 210 | 6.0 | 92 | 4.1 | 1633 | 6.7 |
| *Cirrhosis* | *190* | *14.3* | *0* | *0.0* | *4* | *1.9* | *14* | *15.2* | 208 | *12.7* |
| *Fatty liver* | *536* | *40.4* | *3* | *75.0* | *104* | *49.5* | *39* | *42.4* | 682 | *41.8* |
| *Liver failure* | *65* | *4.9* | *0* | *0.0* | *6* | *2.9* | *3* | *3.3* | 74 | *4.5* |
| *Necrosis* | *17* | *1.3* | *0* | *0.0* | *3* | *1.4* | *3* | *3.3* | 23 | *1.4* |
| Skin disorders | 4878 | 26.1 | 12 | 17.9 | 700 | 20.1 | 331 | 14.6 | 5921 | 24.2 |
| **Total** | **10135** | - | **44** | - | **2190** | - | **831** | - | **13200** | - |

**Abbreviations**: ALS = Amyotrophic lateral sclerosis, MS = Multiple sclerosis.
Note: Marines: male = 17,966, female = 559, and not reported = 180; Civilian Workers: male = 29, female = 35, and not reported = 3; Dependents: male = 888, female = 2,544, and not reported = 46; Unreported affiliation: male = 1,468, female = 541, and not reported = 254.

**Table A5b. Frequency of reported non-cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by affiliation**

| Non-cancer diseases | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | Civilian worker | | Dependent | | Not reported | | Total | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| **Autoimmune** | | | | | | | | | | |
| Lupus | 134 | 1.3 | 1 | 2.3 | 97 | 4.4 | 17 | 2.0 | 249 | 1.9 |
| Scleroderma | 140 | 1.4 | 1 | 2.3 | 30 | 1.4 | 12 | 1.4 | 183 | 1.4 |
| **Nervous system** | | | | | | | | | | |
| ALS | 175 | 1.7 | 0 | 0.0 | 21 | 1.0 | 25 | 3.0 | 221 | 1.7 |
| MS | 102 | 1.0 | 1 | 2.3 | 45 | 2.1 | 7 | 0.8 | 155 | 1.2 |
| Parkinson disease | 239 | 2.4 | 2 | 4.5 | 27 | 1.2 | 17 | 2.0 | 285 | 2.2 |
| **Male reproductive organs** | | | | | | | | | | |
| Infertility | 1218 | 12.0 | 4 | 9.1 | 58 | 2.6 | 64 | 7.7 | 1344 | 10.2 |
| *Abnormal sperm* | *162* | *13.3* | *0* | *0.0* | *8* | *13.8* | *14* | *21.9* | 184 | *13.7* |
| *Low sperm* | *645* | *53.0* | *1* | *25.0* | *37* | *63.8* | *39* | *60.9* | 722 | *53.7* |
| **Female reproductive organs** | | | | | | | | | | |
| Endometriosis | 92 | 0.9 | 7 | 15.9 | 459 | 21.0 | 83 | 10.0 | 641 | 4.9 |
| Infertility | 50 | 0.5 | 5 | 11.4 | 265 | 12.1 | 53 | 6.4 | 373 | 2.8 |
| *Fallopian tube damage* | *21* | *42.0* | *3* | *60.0* | *54* | *20.5* | *14* | *26.4* | 92 | *24.7* |
| **Other** | | | | | | | | | | |
| Aplastic anemia | 273 | 2.7 | 0 | 0.0 | 55 | 2.5 | 20 | 2.4 | 348 | 2.6 |
| Kidney disease | 1507 | 14.9 | 7 | 15.9 | 223 | 10.2 | 110 | 13.2 | 1847 | 14.0 |
| Liver disease | 1327 | 13.1 | 4 | 9.1 | 210 | 9.6 | 92 | 11.1 | 1633 | 12.4 |
| *Cirrhosis* | *190* | *14.3* | *0* | *0.0* | *4* | *1.9* | *14* | *15.2* | 208 | *12.7* |
| *Fatty liver* | *536* | *40.4* | *3* | *75.0* | *104* | *49.5* | *39* | *42.4* | 682 | *41.8* |
| *Liver failure* | *65* | *4.9* | *0* | *0.0* | *6* | *2.9* | *3* | *3.3* | 74 | *4.5* |
| *Necrosis* | *17* | *1.3* | *0* | *0.0* | *3* | *1.4* | *3* | *3.3* | 23 | *1.4* |
| Skin disorders | 4878 | 48.1 | 12 | 27.3 | 700 | 32.0 | 331 | 39.8 | 5921 | 44.8 |
| **Total** | **10135** | **76.8** | **44** | **0.3** | **2190** | **16.6** | **831** | **6.3** | **13200** | **100.0** |

**Abbreviations**: ALS = Amyotrophic lateral sclerosis, MS = Multiple sclerosis.

**Table A6. Frequency of reported non-cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by sex**

| Non-cancer diseases | Sex | | | | | |
|---|---|---|---|---|---|---|
| | Male | | Female | | Not reported | |
| | No. | % | No. | % | No. | % |
| **Autoimmune** | | | | | | |
| Lupus | 130 | 1.2 | 117 | 4.6 | 2 | 1.6 |
| Scleroderma | 153 | 1.5 | 29 | 1.1 | 1 | 0.8 |
| **Nervous system** | | | | | | |
| ALS | 198 | 1.9 | 22 | 0.9 | 1 | 0.8 |
| MS | 108 | 1.0 | 45 | 1.8 | 2 | 1.6 |
| Parkinson disease | 254 | 2.4 | 28 | 1.1 | 3 | 2.4 |
| **Male reproductive organs** | | | | | | |
| Infertility | 1344 | 12.8 | - | - | - | - |
| *Abnormal sperm* | *184* | *13.7* | - | - | - | - |
| *Low sperm count* | *722* | *53.7* | - | - | - | - |
| **Female reproductive organs** | | | | | | |
| Endometriosis | - | - | 641 | 25.3 | - | - |
| Infertility | - | - | 373 | 14.7 | - | - |
| *Fallopian tube damage* | - | - | *92* | *24.7* | - | - |
| **Other** | | | | | | |
| Aplastic anemia | 275 | 2.6 | 72 | 2.8 | 1 | 0.8 |
| Kidney disease | 1573 | 14.9 | 256 | 10.1 | 18 | 14.2 |
| Liver disease | 1388 | 13.2 | 225 | 8.9 | 20 | 15.7 |
| *Cirrhosis* | *205* | *14.8* | *19* | *8.4* | *7* | *35.0* |
| *Fatty liver* | *557* | *40.1* | *117* | *52.0* | *9* | *45.0* |
| *Liver failure* | *63* | *4.5* | *7* | *3.1* | *1* | *5.0* |
| *Necrosis* | *19* | *1.4* | *2* | *0.9* | *2* | *10.0* |
| Skin disorder | 5119 | 48.6 | 730 | 28.8 | 72 | 60.0 |
| **Total** | **10540** | **79.8** | **2538** | **19.2** | **122** | **1.0** |

**Abbreviations**: ALS = Amyotrophic lateral sclerosis, MS = Multiple sclerosis.

**Table A7. Frequency of reported non-cancer outcomes of the U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants who completed a health survey, by race**

| Non-cancer diseases | Race | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | African American | | White | | Other | | Multiracial | |
| | No. | % | No. | % | No. | % | No. | % |
| **Autoimmune** | | | | | | | | |
| Lupus | 38 | 2.3 | 192 | 1.8 | 7 | 2.2 | 12 | 1.7 |
| Scleroderma | 18 | 1.1 | 136 | 1.3 | 14 | 4.4 | 15 | 2.1 |
| **Nervous system** | | | | | | | | |
| ALS | 28 | 1.7 | 163 | 1.6 | 6 | 1.9 | 24 | 3.3 |
| MS | 17 | 1.0 | 126 | 1.2 | 6 | 1.9 | 6 | 0.8 |
| Parkinson disease | 10 | 0.6 | 251 | 2.4 | 8 | 2.5 | 16 | 2.2 |
| **Male reproductive organs** | | | | | | | | |
| Infertility | 204 | 12.3 | 1030 | 9.8 | 31 | 9.8 | 79 | 10.9 |
| *Abnormal sperm* | *29* | *14.2* | *133* | *12.9* | *7* | *22.6* | *15* | *19.0* |
| *Low sperm count* | *99* | *48.5* | *563* | *54.7* | *17* | *54.8* | *43* | *54.4* |
| **Female reproductive organs** | | | | | | | | |
| Endometriosis | 52 | 3.1 | 557 | 5.3 | 13 | 4.1 | 19 | 2.6 |
| Infertility | 46 | 2.8 | 303 | 2.9 | 7 | 2.2 | 17 | 2.3 |
| *Fallopian tube damage* | *20* | *43.5* | *66* | *21.8* | *3* | *42.9* | *3* | *17.6* |
| **Other** | | | | | | | | |
| Aplastic anemia | 59 | 3.6 | 255 | 2.4 | 11 | 3.5 | 23 | 3.2 |
| Kidney disease | 244 | 14.7 | 1466 | 14.0 | 36 | 11.4 | 101 | 13.9 |
| Liver disease | 177 | 10.7 | 1308 | 12.5 | 37 | 11.7 | 111 | 15.3 |
| *Cirrhosis* | *28* | *15.8* | *180* | *13.8* | *4* | *10.8* | *19* | *17.1* |
| *Fatty liver* | *42* | *23.7* | *584* | *44.6* | *15* | *40.5* | *42* | *37.8* |
| *Liver failure* | *11* | *6.2* | *50* | *3.8* | *2* | *5.4* | *9* | *8.1* |
| *Necrosis* | *3* | *1.7* | *16* | *1.2* | *0* | *0.0* | *4* | *3.6* |
| Skin disorder | 762 | 46.0 | 4717 | 44.9 | 139 | 44.1 | 303 | 41.7 |
| **Total** | **1655** | **12.5** | **10504** | **79.6** | **315** | **2.4** | **726** | **5.5** |

**Abbreviations**: ALS = Amyotrophic lateral sclerosis, MS = Multiple sclerosis.

**Table A8. Frequency of pregnancies on base reported by female U.S. Marine Corps Camp Lejeune Historic Drinking Water registrants, by affiliation**

| Pregnancy outcomes | Affiliation | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine | | Civilian worker | | Dependent | | Not reported | | Total | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Live single | 230 | 73.2 | 18 | 75.0 | 914 | 82.8 | 217 | 82.8 | 1379 | 80.9 |
| Live multiple | 4 | 1.3 | 1 | 4.2 | 15 | 1.4 | 6 | 2.3 | 26 | 1.5 |
| Tubal | 4 | 1.3 | 1 | 4.2 | 6 | 0.5 | 1 | 0.4 | 12 | 0.7 |
| Abortion | 9 | 2.9 | 0 | 0.0 | 6 | 0.5 | 0 | 0.0 | 15 | 0.9 |
| Miscarriage | 67 | 21.3 | 4 | 16.7 | 163 | 14.8 | 38 | 14.5 | 272 | 16.0 |
| **Total** | **314** | **18.4** | **24** | **14.1** | **1104** | **64.8** | **262** | **15.4** | **1704** | **100** |