

5.02 - 1/1/96 - 02544

Marine Corps Base Camp Lejeune - Final Release

PUBLIC HEALTH ASSESSMENT

**U.S. MARINE CORPS CAMP LEJEUNE
MILITARY RESERVATION**

CAMP LEJEUNE, ONSLOW COUNTY, NORTH CAROLINA

CERCLIS NO. NC6170022580

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B. Volatile Organic Compound Exposure (Tap Water)

In the past, the Tarawa Terrace, Hadnot Point, and Holcomb Boulevard water distribution systems on base were contaminated with volatile organic compounds (VOCs) (see Table 2). The sources of contamination were leaks from off-base and on-base underground tanks, some of which were installed in the 1940s. People who used water from these systems between 1982 to 1985 were exposed to VOCs. Exposure was intermittent and stopped when the contaminated wells were closed in 1985. From the sampling data, we estimated probable exposure dose levels for adults and concluded that noncancerous and cancerous health effects are unlikely to occur in those adults exposed. For children, we could not determine the likelihood of either noncancerous or cancerous health effects because there is not enough scientific information on the adverse health effects these compounds might have on children. However, there is evidence that suggests that, because of their developing systems, fetuses are potentially more sensitive to the effects of VOCs than either adults or children. Several epidemiologic studies have suggested associations between exposure to VOCs and birth defects, low birthweight, and late fetal death. ATSDR conducted a study of birth outcomes of women who were exposed to VOCs in drinking water at MCB Camp Lejeune during their pregnancy. Interim results of that study, reported in 1997, indicate that for most live births, there was no association between housing supplied with water from the Tarawa Terrace system and decreased mean birthweight (MBW) and increased numbers of babies born small for gestational age (SGA). Associations between the Tarawa Terrace water system and MBW and SGA were observed in two potentially susceptible subgroups: infants of mothers age 35 and older and infants whose mothers had histories of fetal deaths. For mothers whose housing was supplied with water from the Hadnot Point system, decreased MBW and increased SGA were observed in male, but not in female, infants. Decreased MBW and increased SGA were not associated with housing supplied by the Holcomb Boulevard system. The findings for both Hadnot Point and Tarawa Terrace were unanticipated because associations were observed in certain subgroups but not others. ATSDR is conducting more research on VOCs in other populations that may confirm or refute the importance of these associations. Final analyses of fetal death and pre-term delivery data collected for the Camp Lejeune pregnancy study will be completed in 1997.

What are VOCs?

VOCs make up a group of chemicals having similar physical properties. VOCs readily evaporate or volatilize into gases when exposed to air. Chemicals in this group include trichloroethylene (TCE), dichloroethylene (DCE), benzene, tetrachloroethylene (PCE), methylene chloride, and vinyl chloride and in general may be used as dry-cleaning solutions, additives in fuels, or as solvents to dissolve grease or other compounds. The major health concerns of these low-level VOC exposures are adverse birth outcomes and cancer in children exposed to VOCs *in utero*. ATSDR's ongoing health study will address birth outcomes. In addition, a study of childhood cancer is recommended.

VOC Sampling

In 1982, MCB Camp Lejeune performed basewide routine sampling of treated drinking water for THMs, a procedure to test for chlorine disinfection by-products. In May 1982, the laboratory noted difficulty in measuring THMs in two of the eight water systems in operation at that time because of interference by unidentified compounds. The analysis was then expanded to include trichloroethylene (TCE) and tetrachloroethylene (PCE), which were thought to be the interfering compounds (27). The findings for each distribution system are summarized below.

Hadnot Point Water Distribution System

At Hadnot Point, tap water samples contained TCE at 1400 ppb and 1,2 dichloroethylene (DCE) at 407 ppb in May 1982, but in July 1982, levels dropped to 20 ppb TCE and 1,2 DCE was not detected (see Table 2) (27). The drop in these levels can be explained by the use of different supply wells (a few containing contamination and others not) on different days. In the Hadnot Point system, any given well would have been in use about two-thirds of the time because water demand did not require using all wells at the same time (28). There were 39 operational wells in the system, but only 20 of those wells were used at any one time. The wells pump water to the distribution system where the water is blended and treated. This process means that although the contamination is then spread from the one well to the entire distribution system, it is also diluted by being combined with water from uncontaminated wells. Chlorine, fluoride, and softeners are added to the water before it is pumped to water towers before distribution (28). The possible sources of contamination at the Hadnot Point distribution system are leaking underground storage tanks containing TCE and fuels, spills during vehicle maintenance operations, and disposal of drums at Sites 6, 9, and 82 and associated storage lots in OU 2 (29, 79).

In July 1984, as part of the Navy Assessment and Control of Installation Pollutants (NACIP) Program, MCB Camp Lejeune conducted water quality sampling in wells on base. They found that eight of the 39 wells in use at Hadnot Point and one of the seven wells in use at Tarawa Terrace were contaminated with various VOCs. All nine wells were abandoned and have not been used in the drinking water system since 1985 (28).

Table 2. Maximum Contaminant Concentrations Detected in On-Base Drinking Water Tap Samples in 1982-1985

Chemical	Maximum Concentration (ppb)			Drinking Water Standard Established 1991* (ppb)
	Hadnot Point	Tarawa Terrace	Holcomb Blvd	
Trichloroethylene (TCE)	1400	8	1148	5
Dichloroethylene (DCE)	407	12	407	7
Tetrachloroethylene (PCE)	ND	215	ND	5
Methylene Chloride	54	ND	ND	5
Vinyl Chloride	3 J†	ND	ND	2

* - EPA's Drinking Water Standard, referred to as the Maximum Contaminant Level (MCL) allowable

ND - None Detected

J - Estimated Value

† - Detection limit was 10 ppb.

Tarawa Terrace Water Distribution System

Tap water sampling in the Tarawa Terrace water system in May 1982 detected PCE at 80 ppb, a level that remained consistent during the July sampling. 1,2-DCE was detected at 12 ppb. Trace amounts TCE were detected, but because of the laboratory instrument detection limit of 10 ppb, TCE was estimated to be 8 ppb. At the time of the 1982 sampling, no source for the contamination at either Hadnot Point or Tarawa Terrace system had been identified (31). Furthermore, there were no drinking water standards for these chemicals in 1982; TCE, PCE, and 1,2-DCE levels in drinking water were not regulated until the Safe Drinking Water Act was amended in 1991 (32). Sampling in February 1985 detected PCE at 215 ppb. Table 2 shows the maximum detected concentrations of VOCs at the tap and the current drinking water standard, referred to as the Maximum Contaminant Level (MCL) allowable.

Subsequently, it was determined that contamination at the Tarawa Terrace distribution system was caused by an off-base dry-cleaning operation (ABC Cleaners) whose septic system released the cleaning fluid PCE into the ground (33). The septic system was installed in 1954 and used until 1985. In 1958, a well supplying the Tarawa Terrace system was drilled approximately 900 feet from the dry-cleaners. Because the well was so close to the septic field, the well was probably contaminated soon after it was built. That well could have contaminated the water distribution system with PCE for as long as 30 years. Over time, contaminants migrated into a second base well, located approximately 1800 feet south of the septic system, but the PCE contamination was detected before this well was put into use. In 1985, both of these contaminated wells were shut down (31). Unable to meet the increasing water demand without those wells, the Tarawa Terrace distribution system was closed (28). This public health assessment evaluates exposures that occurred during the time for which sampling data are

available. However, the ATSDR study of birth outcomes reviewed available birth records over the longer estimated exposure duration (1958-1985).

Holcomb Boulevard Water Distribution System

On January 27, 1985, a generator fuel line at the Holcomb Boulevard water distribution plant burst, leaking fuel into the system. This situation was identified after the base received complaints of a gasoline smell in on-base residential tap water (31). MCB performed sampling of the system and found that gasoline had entered the Holcomb Boulevard distribution system. The system was immediately shut down and flushed out. Emergency back-up water was then pumped from the Hadnot Point system, whose VOC contamination was not yet identified, into the Holcomb Boulevard distribution lines. Tap water samples taken from Berkeley Manor Elementary School in the Holcomb Boulevard system on January 31, 1985, contained TCE at 1148 ppb and DCE at 407 ppb (Table 2). Contaminants measured at several points in the Holcomb Boulevard system were consistent with samples taken from the Hadnot Point Water treatment plant on the same date. Therefore, the source of TCE and DCE in the Holcomb Boulevard system originated from the contaminated emergency water supplied by the Hadnot Point system. People were switched back to the clean Holcomb Boulevard system 12 days later when the generator fuel line was repaired (31).

Human Exposure Route and Public Health Implications

Our exposure estimates assume that people were exposed to VOCs in drinking water during the time tap water sampling data showed contamination of the water systems. People drinking or bathing with water supplied by Hadnot Point and Tarawa Terrace water distribution systems during 1982 to 1985 were exposed to VOCs. Most likely, contamination was present before 1982, but there is no sampling information to confirm this assumption. Because of the random use of contaminated wells (water demand did not require all wells to be in use at the same time), we estimated exposures to be intermittent, occurring off and on, for 3 years, 1982-1985. See Table 3. The base residents and employees exposed included adults, children, and fetuses.

Holcomb Boulevard distribution system received contaminated drinking water for 12 days in 1985 when a broken pipe emergency required that back-up water be piped in from the Hadnot Point system, which contained VOC contamination. Therefore, people drinking or bathing with water from Holcomb Boulevard water distribution system from January 27 to February 7, 1985, were exposed to VOCs on a short-term basis (less than 14 days).

In general, exposure to VOCs in water can occur from ingestion, inhalation, or skin contact with contaminated water. Because these chemicals readily change from liquid form to vapor, showering, bathing, and cooking can contribute to the estimated exposure dose. Reports in the scientific literature indicate that, while showering, people generally inhale an amount of VOCs equivalent to drinking 2 liters of water (34). Our VOC exposure estimates assume exposure to

VOCs from ingesting 2 liters of water per day and inhaling an equivalent concentration of VOCs during showering. The estimated exposure doses for people drinking contaminated water in these three systems are presented in Table 3.

TCE is similar to PCE in chemical composition and in the way the body metabolizes it. However, we have evaluated the effects of each chemical separately, and those results are presented in Table 3. We also qualitatively consider the combined effects of the chemicals on the body when evaluating the likelihood of cancer.

Noncancerous adverse health effects are not expected for the adults who were exposed to VOCs by drinking or bathing in the contaminated water at MCB Camp Lejeune. During the 1940s and early 1950s, TCE and PCE were used to anesthetize patients during operations. A review of available information on those people and also information on occupational exposures indicates that short-term exposure to TCE, regardless of route (ingestion, inhalation, or skin absorption) at concentrations of 100 to 10,000 times greater (160,000–1,000,000 ppb) than those detected at MCB Camp Lejeune depress the central nervous system, causing headache, dizziness, nausea, vomiting, and intoxication (35). Long-term exposure to TCE at 200,000–400,000 ppb, which is 142 to 285 times higher than the levels detected at MCB Camp Lejeune, as reported in the scientific literature caused vertigo, short-term memory loss, and harmful liver and kidney effects (35). Because the concentrations of TCE detected in the drinking water at MCB Camp Lejeune are so much lower (100 to 10,000 times lower) than the levels causing the previously mentioned effects, it is unlikely that adults would have developed noncancerous adverse health effects. More recently, very subtle effects of TCE on nervous system reflexes have been observed after long-term exposure to no more than 35,000 ppb (36). However, these subtle effects were observed in a population exposed to TCE for 20 years, which is much longer than most residents at MCB Camp Lejeune would have received contaminated water.

Certain people are potentially more sensitive to the effects of VOCs. These more sensitive groups include chronic consumers of alcohol, people with heart disease, people taking disulfiram (a medication used to treat alcoholism), and people taking the anticoagulant warfarin (37). These medications increase the toxicity of VOCs on the liver.

Table 3. Potential Health Effects for VOC Exposures

Water System	Exposed Population	Exposure Time Frame	Exposure Activity	Drinking Water Contaminant		Estimated Exposure Dose (mg/kg/day)	Potential Health Effects	
				Chemical	Maximum Concentration (ppb)		Noncancer Effects	Cancer Risk Increase †
Hadnot Point	Base residents and workers (Adults, children, and fetuses)	Past known 1982-1985, unknown 1940s-1982	People in the Hospital Point housing complex and other buildings supplied by the Hadnot Point Drinking Water System ingesting, inhaling, and having dermal contact with contaminated drinking water	TCE	1400	Adult 1.7E-03	Not Likely	No
						Child 3.7E-03	Unknown	Unknown
				DCE	407	Adult 4.9E-04	Not Likely	No
						Child 1.1E-03	Not Likely	Unknown
				Methylene Chloride	54	Adult 6.6E-05	Not Likely	No
						Child 1.4E-04	Not Likely	Unknown
Vinyl Chloride	3 J	Adult 3.6E-06	Not Likely	No				
		Child 8.1E-06	Not Likely	Unknown				
Tarawa Terrace	Base residents (Adults, children, and fetuses)	Past known 1982-1985, unknown 1954-1982	People in the Tarawa Terrace housing complexes ingesting, inhaling, and having dermal contact with contaminated drinking water supplied by Tarawa Terrace Drinking Water System	TCE	8	Adult 9.8E-06	Not Likely	No
						Child 2.2E-05	Not Likely	Unknown
				DCE	12	Adult 1.5E-05	Not Likely	No
						Child 3.2E-05	Not Likely	Unknown
				PCE	215	Adult 2.6E-04	Not Likely	No
						Child 5.8E-04	Unknown	Unknown
Holcomb Blvd	Base residents and workers (Adults, children, and fetuses)	Past known January 27 -February 7, 1985	People in the Paradise Point, Watkins Village, Berkeley Manor, Midway Park housing complexes, and other buildings supplied by the Holcomb Boulevard Drinking Water System ingesting, inhaling, and having dermal contact with contaminated drinking water	TCE	1,148	Adult 3.3E-05	Not Likely	No
						Child 7.2E-05	Unknown	Not Likely
				DCE	407	Adult 1.2E-05	Not Likely	No
						Child 2.5E-05	Not Likely	Not Likely

† - Increased cancer risk is based on $\geq 5.5 \times 10^{-5}$.

J - Estimated value

NOTE: Dose calculations and cancer risk estimates are included in Appendix F-2.

The Probable Health Effects does NOT include those for fetuses, which would be unknown.

Cancerous Effects

Typically, ATSDR uses human epidemiologic and occupational studies when evaluating the likelihood of cancerous effects or cancer risk. However, too few epidemiologic studies have been carried out on low-level exposure to VOCs to make sound cancer estimates. Therefore, we decided to base our assessment of cancer risk from exposure to VOCs at MCB Camp Lejeune on data from animal studies. The International Agency for Research in Cancer (IARC) classifies TCE and PCE as "probably carcinogenic to humans" based on "sufficient" evidence of carcinogenicity in animals and "limited" evidence in humans (38). The animal studies evaluated the cancer effects from known exposure to VOCs. On the basis of these animal studies, mathematical formulas were derived using factors to convert animal data into values relevant to humans.

Using cancer risk estimates, ATSDR determined that cancerous health effects are unlikely in adults who were exposed to VOCs in drinking water at MCB Camp Lejeune (Appendix E-1). Although cancer is not expected to occur, not enough scientific information on humans is available to rule out the possibility of cancerous health effects from low-dose exposure to VOCs. A few epidemiologic studies have suggested that exposure to VOCs may be associated with leukemia, non-Hodgkins lymphoma, and bladder and kidney cancer (39, 40, 41, 42). The exposure doses in these studies were similar to or slightly higher than what was estimated for people at MCB Camp Lejeune. However, there are too few studies to see any definite pattern of cancers related to VOC exposure. In addition, these studies are further limited methodologically because of the difficulty of verifying and quantifying people's exposure to VOCs. Because the results of the epidemiologic studies suggest a possibility of cancer from exposure to VOCs at low doses, more studies are needed to adequately address the issue of human cancer associated with low-dose VOC exposure.

Health Outcome Data

Cancer Data

At this time, ATSDR is not planning a follow-up cancer statistics evaluation of adults at MCB Camp Lejeune for the following reasons. A simple review of cancer statistics from the North Carolina cancer registry would not be useful because cancer registries contain cancer cases diagnosed each month for a specific county. When exposures occur, generally all residents of the county are not equally affected. Instead, the people exposed would be a smaller, localized group such as the small group of residents at Tarawa Terrace, MCB Camp Lejeune. Therefore, evidence of higher cancer rates in groups this small may be hidden within the rates of cancer for the entire county.

In addition, latency for most types of cancer is between 10 and 20 years. This creates two problems. First, those exposed to potential VOC carcinogens in the 1982-1985 time frame, would just now be beginning to be diagnosed with cancer. Secondly, the average stay of residents at MCB Camp Lejeune at that time was 3 years, and most of the exposed individuals

who develop cancer are likely to have moved before they are diagnosed. Hence, most of the cancer cases that might have occurred among exposed individuals would not be recorded in the North Carolina cancer registry as occurring to MCB Camp Lejeune residents.

The potential effects of VOC exposure on children have been evaluated only in Woburn, Massachusetts, where a cluster of childhood leukemia cases has been investigated in several different studies. The Woburn studies suggested an association between childhood leukemia and access to VOC-contaminated drinking water (42, 43, 44). This association was quite strong in children who were exposed to the largest quantities of VOCs *in utero* (43). In addition, cancer rates declined to expected levels about 8 years after the contaminated wells were closed, which is a reasonable latency period for childhood cancer. The contaminant levels in the Woburn wells were TCE, 267 ppb; PCE, 21 ppb; chloroform, 12 ppb; and other VOCs. The wells were used 59% of the time, and water was blended with water from six other municipal wells, thus lowering the actual concentrations of VOCs people would be drinking at their taps. The risk of childhood leukemia associated with VOC-contaminated drinking water in Woburn was impossible to estimate precisely because the overall number of childhood leukemia cases in Woburn was small, the number of years during which Woburn water was contaminated was not known, and what VOC concentrations were present in tap water was not known. In addition, some associations between chemical exposure and disease arise by coincidence. This is why it is necessary to conduct epidemiologic studies in several different populations to establish a definitive link between exposure and disease. Nevertheless, the findings at Woburn raise concerns about potential childhood cancer risks associated with VOC exposure *in utero*. Therefore, we recommend that, if feasible, ATSDR conduct a study of cancer in children potentially exposed to VOCs *in utero* while their parents resided at Camp Lejeune.

Noncancerous Effects

Adverse Birth Outcomes

Women may experience adverse pregnancy outcomes from exposure to toxic substances even when their own health is not threatened, because fetuses are potentially more sensitive to the effects of VOCs (45, 46). Several epidemiologic studies suggested the possibility that pregnant women exposed to VOCs (at levels similar to those detected at MCB Camp Lejeune) may have an increased risk of adverse pregnancy outcomes. The outcomes include birth defects such as heart malformations, neural tube defects, oral clefts, low birthweight, and increased fetal death (45, 46-51). Some of these studies have significant limitations, including questions about whether all of the study population was exposed, how long exposure took place, and the exact concentrations of VOCs to which these mothers were exposed. Due to these limitations, more studies are needed to better evaluate the relationship between VOC exposure and adverse pregnancy outcomes.

To help address the issue about pregnancy outcomes, ATSDR began a study at Camp Lejeune in 1995. In an interim report released in 1997, ATSDR identified approximately 6000 infants whose mothers resided in VOC-exposed housing areas while pregnant (52, 53). A statistically

significant decrease in mean birthweight and a statistically significant increase in the condition small for gestational age was observed in *male infants* born to mothers whose housing was supplied with water from *Hadnot Point*. Birthweight in this group was compared with birthweight of infants of women living in other officers' housing. No differences in mean birthweight or the condition small for gestational age were noted in most residents receiving water from Tarawa Terrace compared with residents of other housing areas. However, in Tarawa Terrace residents, the children of mothers who were *35 years of age or older* and the children of mothers who had *previously had a fetal loss* were more likely to have been born small for gestational age. Infants whose mothers were very briefly exposed to VOCs from the Holcomb Boulevard system were not more likely to have lower mean birthweight or to be born small for gestational age.

Summary and Follow-up

Human exposure to TCE, PCE, and 1,2-DCE in drinking water systems at MCB Camp Lejeune has been documented over a period of 34 months, but likely occurred for a longer period of time perhaps as long as 30 years. Included in the population that used this water were approximately 6000 residents in base family housing (52, 53). This population consisted of a large proportion of young married women. Even though adverse health effects are not expected in adults, concern was raised about potential toxic effects on developing fetuses.

As discussed previously, it is difficult to draw conclusions from a single epidemiologic study, and most of the other epidemiologic studies completed to date have been so different in study design that their results cannot be adequately compared. Also, finding associations in some subgroups but not others is plausible, but was not expected. Research conducted in other groups of infants exposed to these chemicals *in utero* will be necessary before firm conclusions about the effects of low-level VOC exposure on birthweight can be drawn. ATSDR is currently conducting another study of TCE in drinking water and birthweight as part of its National Exposure Registry activities. The Exposure Registry study may confirm or refute some of these observations. A future report based on the Camp Lejeune birth data will examine the potential association between VOC exposure and preterm delivery and late fetal death. Birth defects will be studied only briefly because the data are too limited for an adequate evaluation.

Another potential effect of fetal exposure to VOCs is childhood cancer. Information about the potential for this effect is limited, but provocative. Therefore, ATSDR recommends a study of cancer in children who were exposed to VOCs at MCB Camp Lejeune while *in utero*.

Conclusions and Public Health Action Plan for VOC Exposure (Tap Water)

Conclusion:

1. Before 1986, people drinking and showering with water from the Tarawa Terrace, Hadnot Point, and the Holcomb Boulevard water distribution systems on base were exposed to volatile organic compounds (VOCs). There is information documenting drinking water contamination in the Tarawa Terrace and Hadnot Point water systems from 1982 until 1985, although contamination could have been present longer. Contamination in the Holcomb Boulevard system was present only for two weeks, January 27- February 7, 1985. At the estimated exposure levels, we do not expect cancerous or noncancerous health effects in adults. Even though ATSDR determined that cancerous health effects are unlikely in children, not enough scientific information is available to rule out the possibility of cancerous health effects from low-dose exposure to VOCs such as those at MCB Camp Lejeune. Additionally, fetuses are potentially more sensitive than children to VOCs. Previous studies have suggested associations between childhood cancer, low birthweight, late fetal death, and fetal exposure to VOCs.
2. ATSDR's Health Study suggests that a statistically significant decrease in mean birthweight and a statistically significant increase in the condition small for gestational age was observed in *male infants* born to mothers whose housing was supplied with water from *Hadnot Point*. A copy of the health study can be obtained at the Onslow County Library, Jacksonville, NC, or from ATSDR.
3. ATSDR also found that in Tarawa Terrace residents exposed to VOCs, the children of mothers who were 35 years of age or older and the children of mothers who had *previously had a fetal loss* were more likely to have been born small for gestational age. Infants whose mothers were very briefly exposed to VOCs from the Holcomb Boulevard system were not more likely to have lower mean birthweight or to be born small for gestational age.

Completed Action:

1. In 1985, MCB Camp Lejeune ceased use of VOC-contaminated drinking water wells at Hadnot Point, Tarawa Terrace, and Holcomb Boulevard.

Ongoing Action:

1. In 1995, ATSDR completed collecting data for a study of VOCs in drinking water and birth outcomes at MCB Camp Lejeune. An interim report was released in 1997. A final report is also expected in 1997.

Recommended Action:

1. ATSDR recommends that a study be conducted of cancer in children who were probably exposed *in utero* to VOCs at MCB Camp Lejeune. This study would further the understanding of the health effects of low-dose VOC exposure in susceptible populations, and provide parents with information about their children's health risks.