Health Consultation

VOLUNTEER ARMY AMMUNITION PLANT

CHATTANOOGA, HAMILTON COUNTY, TENNESSEE

EPA FACILITY ID: TN6210020933

FEBRUARY 15, 2005

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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CHATTANOOGA, HAMILTON COUNTY, TENNESSEE

EVALUATION OF EXPLOSIVE COMPOUNDS IN RESIDENTIAL WELLS

EPA FACILITY ID: TN6210020933

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services

Summary

The Volunteer Army Ammunition Plant (VAAP) is an inactive ammunition plant located about 4 miles northeast of Chattanooga in Hamilton County, Tennessee (IT Corp 1994). The U.S. Army, the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environmental Quality (TDEQ) are working to remediate the existing environmental contamination and ready the property for transfer to the City of Chattanooga and Hamilton County. ATSDR completed a public health assessment (PHA) of the site on September 7, 2004.

On September 21, 2004, ATSDR was asked to review groundwater data from three residential wells located near VAAP to evaluate whether residents who had been using the residential well water could experience adverse health effects if the well water contained 2,4,6-trinitrotoluene (TNT), 2,4-dinitrotolue (2,4-DNT), and 2,6-dinitrotolue (2,6-DNT) (in general referred to as "nitrocompounds"). ATSDR was specifically asked whether residents who used the water for daily consumption, for filling swimming pools, for irrigation of vegetable gardens, or for watering their horses had been exposed to levels of nitrocompounds that would be expected to cause health problems.

Some discrepancies appear in the measured data. Nitrocompounds were not detected in any of the residential well samples collected in January 2001 or in October 2004. During these sampling events the detection limits the detection limits of the analytical procedures were within the necessary range to compare measured concentrations to conservative health-based screening values. For the samples collected in September 2004, one laboratory's analysis reported the presence of nitrocompounds while another laboratory's analysis did not find nitrocompounds in the water. Therefore, some uncertainty exists regarding the actual concentration of nitrocompounds in residential wells in September 2004.

Due to these uncertainties, ATSDR cannot be certain that residents were exposed to nitrocompounds. Although residents may not have actually been exposed to nitrocompounds, ATSDR, as a conservative measure, chose to evaluate the potential health effects for residents as if they had been exposed to the highest reported concentration of each nitrocompound found in the September 2004 water sample. The highest measured concentrations reported from the September 2004 data may significantly overestimate the actual concentration, and the estimated potential exposure to the nitrocompounds may be significantly overestimated. Therefore, the following conclusions, which are based on the uncertain data from September 2004, are the result of an evaluation designed to consider "worst-case" exposure conditions.

Conclusions

Results of the evaluation indicate that persons who used well water with the maximum concentrations reported in the September 2004 data would not be expected to have health problems. This evaluation considered exposure from drinking the well water daily, swimming in pools filled with well water, and eating vegetables from gardens irrigated with well water. ATSDR was not able to evaluate whether horses watered primarily with well water would be expected to develop health effects. Residents who are concerned about potential health effects for pets for whom well water is the primary drinking source should consult a veterinarian for advice.

Background

Site Description and History

The Volunteer Army Ammunition Plant (VAAP) is an inactive ammunition plant located approximately 4 miles northeast of Chattanooga's city center in Hamilton County, Tennessee (IT Corp 1994). VAAP was built to manufacture 2,4,6-trinitrotoluene (TNT) for the U.S. Army in 1942. TNT production occurred intermittently to support World War II, the Korean War, and the Vietnam War. Historic spills and waste disposal practices resulted in groundwater contamination, the most significant of which is localized in the TNT Manufacturing Valley in the western portion of the installation (TDEC 2003a).

Groundwater sampling data is periodically gathered from monitoring wells located on the installation, off-post monitoring wells, and neighboring residential wells. At the time the public health assessment (PHA) was completed, ATSDR was under the impression that all residents near VAAP were currently connected to municipal drinking water supplies for their domestic uses (Shaw 2003), although some homeowners continued to use water from private wells for gardening, filling swimming pools, and other nonpotable uses (TDEC 2003a).

During a September 2004 sampling event, samples from three residential wells were analyzed by two different laboratories. Results from one laboratory indicated the concentrations of nitrocompounds were above drinking water standards (from EPA Regions 3 and 9) and ATSDR's health-based comparison values. Results from another laboratory indicated nitrocompounds were either not detected or below all of the screening values. Analysis of subsequent samples collected in October 2004 did not find nitrocompounds in any of the residential wells. The detection limits of the analytical procedures were within the range necessary to compare measured concentrations to health-based screening values.

On September 21, 2004, ATSDR was asked to review the sampling data from the three residential wells. ATSDR was asked to evaluate whether residents who used water from their private wells could have been exposed to contaminant concentrations at levels that could cause harmful health effects. Specifically ATSDR was asked to consider the following potential exposure scenarios:

1. Use of residential well water for all domestic uses
2. Use of residential well water for filling swimming pools
3. Use of residential well water for gardening
4. Use of residential well water for watering horses

ATSDR was provided with a summary of the groundwater sampling results for the three private residential groundwater wells (updated to include the October 2004 sampling results) (Table 1). Due to the uncertainty about the actual concentration of nitrocompounds in the residential wells in September 2004, ATSDR cannot specify residents' actual exposure to nitrocompounds. While residents may not have actually been exposed, ATSDR chose to use the highest reported concentration of each nitrocompound from the September 2004 data to evaluate whether adverse health effects would be expected following the use of water containing nitrocompound concentrations at the reported levels. Therefore, residents' potential exposure to nitrocompounds may be significantly overestimated, and actual exposure could be much less than that estimated.

Summary of Measured Data

The groundwater sampling data used in this evaluation were analyzed at different laboratories and using different analysis methods. Previous reports indicate one residential well was sampled in 1990. However, the available information does not specifically identify the laboratory or analysis method. The results of this sampling event indicate low levels of nitrocompounds were detected, but the analysis methods were not sensitive enough to quantify the actual concentration. Samples obtained from each of the residential wells in January 2001 were analyzed by EPA. Nitrocompounds were not detected in any of the wells, and the sensitivity of the analytical method was equal to the conservative health-based comparison values. Samples obtained from the residential wells in September 2004 and analyzed by one laboratory (GPL) using method 8095 reported nitrocompound concentrations above the comparison value. Using the same samples and the same analysis method (8095), another laboratory (COE) reported the nitrocompound concentrations as very low or not detected. Samples obtained in October 2004 were analyzed by two different methods including the EPA-approved 8330 method. Analysis indicated that nitrocompounds were not detected in any of the residential wells.

The Army, EPA, and TDEQ have investigated the cause behind the variability in results for the September 2004 samples. However, the actual cause of the variation has not been identified. While there is some uncertainty about the actual contaminant concentrations, ATSDR used the highest reported concentration for each of the nitrocompounds for the exposure evaluation. This was done to evaluate whether health effects would be expected if the actual concentrations were as high as the maximum reported values (Tables 2 and 3).

Evaluation

Upon receipt of the laboratory results, the Army began providing bottled water to the residents. Residents were given the option to be connected to the municipal water supply. Currently residents are not exposed to nitrocompounds in their drinking water. Residents who use their groundwater for other nondrinking applications may have some exposure to nitrocompounds if nitrocompounds are actually in the water.

To evaluate these potential exposures, ATSDR used the maximum concentration measured for each of the nitrocompounds to conservatively estimate the potential exposure of the residents with potentially impacted drinking water wells. The following sections describe the assumptions and results of each evaluation. Details are provided in the tables in Appendix A.

Would drinking water containing the maximum concentrations of nitrocompounds reported in the September 2004 data be expected to cause health problems?

No.

Regulatory drinking water standards are based on the assumption that people drink 2 liters (L) (a little over 2 quarts) of water from the same source every day for 70 years. The standards are set very low to be protective of potential lifetime exposures. In reality most people substitute milk, juice, or commercially prepared soft drinks in place of some their water consumption. In addition, most people consume a portion of their daily water intake at work, school, or other facilities, and therefore they do not consume all of their water from their home water source.

ATSDR estimated the daily ingestion rate of each nitrocompound using the following assumptions:

1. The nitrocompound concentration was consistently equal to the maximum concentration reported in the September 2004 data
2. All daily water consumption would come from that source
3. That source would be used every day for 70 years

ATSDR compared the estimated nitrocompound ingestion rate to established health guidelines for each chemical (Tables 4, 5, 6). The health guideline for a particular chemical was established by EPA or ATSDR scientists or both on the basis of detailed information about the potential health effects following continuous ingestion of the chemical. The guidelines identify ingestion rates that scientific information shows will not cause health problems. Because several safety factors were included in determining the health guideline, people who ingest more than the level specified by the guideline will not necessarily develop health problems.

ATSDR reviewed available toxicologic and epidemiologic studies describing research to evaluate the potential for nitrocompounds to cause cancer (Tables 7, 8, and 9). While there is little information about what actually causes cancer, a significant amount of research has been done to identify whether certain conditions or behaviors have been associated with an increased incidence of cancer or an increase in the theoretical risk of developing cancer. The studies reviewed by ATSDR indicate that exposure to high concentrations of TNT and DNT could result in an increase in cancer of the liver or urinary track. However, these concentrations are much higher than the maximum concentrations reported in the September 2004 data. In addition, the exposure at which those health effects were observed were hundreds to millions of times higher than those estimated based on continuous use of drinking water at the nitrocompound concentrations reported in the September 2004 data. *Exposure to nitrocompounds, at the maximum concentrations reported in the September 2004 data, has not been associated with an increase in cancer.*

Would swimming in water containing the maximum concentrations of nitrocompounds reported in the September 2004 data be expected to cause health problems?

No.

ATSDR considered the primary potential exposure to nitrocompounds while swimming to come from incidental ingestion of pool water. The ingestion rate of each nitrocompound was calculated using the same procedure described for drinking water. In this case ATSDR assumed the following:

1. Both children and adults would accidentally ingest 300 millileters of water (approximately 10 ounces) each day that they swam
2. Both children and adults would swim every day for 6 months (183 days per year)

It is possible that the nitrocompound concentrations in the pool water could be lower than that measured in the well due to degradation in the pool. While nitrocompounds do not degrade significantly by hydrolysis, degradation is relatively rapid in natural surface water due to photolysis. Degradation due to microbial metabolism also occurs, only at rates slower than photolysis. Estimates of the half-life are typically less than 48 hours. However, no information is available to identify how chlorination, used in pools to prevent growth of harmful microorganisms, might affect these transformation processes for TNT. DNT degradation appears to be accelerated by chlorination (ATSDR 1995, 1998). To be conservative, the effects of potential degradation processes were not considered in this analysis. ATSDR used the maximum nitrocompound concentrations reported in the September 2004 data.

ATSDR compared the estimated ingestion rates (Tables 10 and 11) to the same health guidelines described in the drinking water evaluation (Table 12) and the toxicologic and epidemiologic studies evaluating the potential for nitrocompounds to cause cancer (Tables 7 and 8). *Results indicate swimming in pools filled with water having the maximum nitrocompound concentrations reported in the September 2004 data would not be expected to cause any adverse health effects.*

Would health problems be expected if people ate vegetables from gardens irrigated with water containing the maximum concentrations of nitrocompounds reported in the September 2004 data?

No.

Only a few papers were identified that described the potential of plants to incorporate TNT or DNT found in the soil or irrigation water into their tissue. Most researchers are attempting to identify plants and growing conditions that result in the greatest accumulation of nitrocompound into the plant tissue from the environment for future environmental remedial activities. Current research suggests that few plants strongly bioaccumulate nitrocompounds from soil or irrigation water, and those that do tend to store the nitrocompounds in the roots (Hughes et al 1997, Kim et al 2004, Price et al 2002, Scheidemann et al 1998, Schneider et al 1996, Sun et al 2000, Sung et al 2003). Vegetable plants studied include corn, tomato, lettuce, radish, and onion (Kim 2004, Price 2002); the remaining studies used grasses or did not identify the plant type. While all of these studies provide general information about the distribution of nitrocompounds between the environmental media and plant tissue, few provide quantitative information about the concentrations of nitrocompounds found in the plant tissue.

The limited accumulation of nitrocompounds in plant material is consistent with the basic chemical properties of TNT and DNT. Nitrocompounds applied to a garden in irrigation water would be subject to a variety of natural processes that would limit the amount of interaction of the compound with the plant, particularly the root. First, the nitrocompounds can be degraded by sunlight which could reduce their available concentration in the irrigation water on the soil surface. Second, nitrocompounds are not strongly sorbed to soil particles or plant tissue, they are available for microbial degradation. Finally, microbial degradation occurs readily in soil, having an estimated half-life of one month. This suggests that microbial degradation is not likely to significantly reduce the nitrocompound concentration in the irrigation water that comes into contact with the plant root; however, significant concentrations of nitrocompounds are not likely to accumulate in the soil (ATSDR 1995, 1998).

ATSDR conservatively estimated the potential ingestion exposure to nitrocompounds in root vegetables irrigated with water containing the maximum measured nitrocompound concentrations based on the following assumptions:

1. No degradation of the nitrocompound occurred.
2. The garden was irrigated every other week for 4 months (8 irrigations).
3. The root absorbed all of the nitrocompound within 3 centimeters (cm) (approximately [~] 1½ inches) of the root surface during each irrigation.
4. The root vegetable size could be approximated as a cylindrical carrot: 3 cm (~1½ inches) in diameter, 20 cm (~ 8 inches) long, and weighing 100 grams (~ 3.6 ounces).
5. Soil porosity was approximately 30%; the infiltrating irrigation water volume would be approximately 30% of the 3-cm thick cylindrical volume along the length of the root.
6. The nitrocompound concentration in the vegetable could be approximated as the total amount of the nitrocompound applied to the 3-cm cylinder of soil around the root during each of the 8 irrigation events.
7. Consumers ate homegrown vegetables 120 days each year, with adults and children respectively eating 300 and 150 grams of vegetables each day (one serving of vegetables, ½ cup of cooked vegetables, is approximately 50 to 75 grams).

Results (shown in Tables 13–17) indicate that using water with the maximum nitrocompound concentrations reported in the September 2004 data to irrigate a vegetable garden would not be expected to cause any adverse health effects. As a prudent health action, consumers should wash all produce thoroughly to remove both naturally occurring and synthetic contaminants.

Would water containing the maximum concentrations of nitrocompounds reported in the September 2004 data be expected to cause health problems for horses?

ATSDR did not find information in existing scientific studies about the possible health effects that nitrocompounds might have on large animals such as horses. ATSDR did estimate the potential nitrocompound ingestion for horses based on the assumption that all of their water came from a source with nitrocompound concentrations equal to the highest reported values in the September 2004 data (Tables 18 and 19). The estimated exposures are less than those described in studies where small animals developed some health effects. However, there can be some interspecies variation; the actual effect to horses is not well studied. *Residents who are concerned about potential effects for pets for whom well water is the primary drinking source should consult a veterinarian for definitive advice*

Authors, Technical Advisors

Susan Neurath, Ph.D.
CDR, U.S. Public Health Service
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Angel Sanchez, MPH
LT, U.S. Public Health Service
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

Gary Campbell, Ph.D.
Environmental Health Scientist
Federal Facilities Assessment Branch
Division of Health Assessment and Consultation

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Appendix A

Data Analysis

Table 1.

Summary of Residential Well Sampling Results (contaminant concentrations in micrograms per liter [µg/L])

Well Identification	Contaminant	Aug 1990 UW01/99	Jan 2001 EPA* 8330	July 2004 GPL† 8095	Sept 2004 GPL† 8095	Sept 2004 COE-V* 8095	Sept 2004 COE-O* 8330	Oct 2004 STL-T† 8321	Oct 2004 STL-T† 8330	CREG
RES 16	TNT	3.9 LT	0.05 ND	1.7	0.93 E	0.032	0.25 ND	0.06 ND	0.2 ND	1
	2,4-DNT	3 LT	0.05 ND	2	3.5 E	0.023	0.24 ND	0.06 ND	0.2 ND	0.05
	2,6-DNT	2.8 LT	0.05 ND	0.55	0.57 E	0.026	0.25 ND	0.06 ND	0.2 ND	0.05
RES 34	TNT	NS	0.05 ND	NS	2.4 E	0.017 #J	NS	0.06 ND	0.2 ND	1
	2,4-DNT	NS	0.05 ND	NS	8.3 E	0.02 ND	NS	0.06 ND	0.2 ND	0.05
	2,6-DNT	NS	0.05 ND	NS	0.99 E	0.02 ND	NS	0.06 ND	0.2 ND	0.05
RES 45	TNT	NS	0.05 ND	NS	0.98 E	0.02 ND	NS	0.06 ND	0.2 ND	1
	2,4-DNT	NS	0.05 ND	NS	5.8 E	0.02 ND	NS	0.06 ND	0.2 ND	0.05
	2,6-DNT	NS	0.05 ND	NS	0.65 E	0.02 ND	NS	0.06 ND	0.2 ND	0.05

* = Government laboratory
† = Private laboratory
LT = Below detection limit
ND = Not detected
E = Above the laboratory's highest standard
NS = Not sampled
J = Estimated value
# = Results of the conformational analysis varied slightly from the original analysis
CREG = Cancer risk evaluation guide, ATSDR’s comparison value for potential cancer health effects

Table 2.

Range of Residential Well Sampling Results for 2004

Well Identification	Contaminant	Minimum µg/L	Maximum µg/L
RES 16	TNT	0.032	1.7
	2,4-DNT	0.023	3.5 E
	2,6-DNT	0.026	0.57 E
RES 34	TNT	0.017 #J	2.4 E
	2,4-DNT	0.02 ND	8.3 E
	2,6-DNT	0.02 ND	0.99 E
RES 45	TNT	0.02 ND	0.98 E
	2,4-DNT	0.02 ND	5.8 E
	2,6-DNT	0.02 ND	0.65 E

µg/L =microgram per liter
E = Above the laboratory's highest standard
ND = Not detected
J = Estimated value
# = Conformational analysis results varied slightly from the original analysis

Table 3.

Maximum Reported Concentrations Used in This Evaluation

Contaminant	Evaluation Concentration (in micrograms per liter [µg/L])
TNT	2.4 E
2,4-DNT	8.3 E
2,6-DNT	0.99E

E = Above the laboratory's highest standard

Estimated Ingestion of Nitrocompounds From Drinking Water

$$\text{Ingestion} = (C \times IR \times EF \times ED) / (BW \times AT)$$

Ingestion = Ingestion rate of the nitrocompound (mg/kg/d)

C = Concentration of nitrocompound in drinking water (mg/L)

IR = Daily drinking water intake rate (L/d)

EF = Exposure frequency (d/yr)

ED = Exposure duration (yr)

BW = Body weight (kg)

AT = Averaging time for exposure period (AT = ED × 365 d/yr) (d)

Table 4.

Summary of Input Values to Estimate Nitrocompound Ingestion From Drinking Water

Input Values	Adult	Child
IR (L/d)	2	1.5
EF (d)	365	365
ED (yr)	70	10
BW (kg)	70	10
AT (d)	25,550	3,650

Table 5.

Summary of Estimated Nitrocompound Ingestion From Consumption of Water Containing the Maximum Nitrocompound Concentrations Measured in Residential Wells

	Maximum Concentration* (µg/L)	Estimated Ingestion Rate (Adult)†,‡ (mg/kg/d)	Estimated Ingestion Rate (Child)†,‡ (mg/kg/L)
TNT	2.4	6.86E-05	3.60E-04
2,4-DNT	8.3	2.37E-04	1.25E-03
2,6-DNT	0.99	2.83E-05	1.49E-04
Sum DNT	9.3	2.66E-04	1.40E-03

∗ Maximum concentration considering all wells

† Assumes that all drinking water is consumed at home; in reality, significant quantities are likely consumed at work, school, or other locations.

‡ Assumes that the residents will be exposed to the maximum concentration measured every day of their lives. In reality, concentrations were lower in the past and with the use of bottled water, current exposure is eliminated. The actual exposure duration was likely only a few years, which means that the ingestion rates would be much lower than the estimated ingestion rates shown in this table.

Table 6.

Comparison of Estimated Nitrocompound Ingestion to ATSDR's Health Guidelines

	Maximum Concentration (µg/L)	Estimated Ingestion Rate (Adult) (mg/kg/d)	Estimated Ingestion Rate (Child) (mg/kg/d)	Comparison Value (mg/kg/d)	Comparison Value and Source
TNT	2.4	6.86E-05	3.60E-04	5.00E-04	ATSDR Intermediate MRL EPA Chronic RfD
2,4-DNT	8.3	2.37E-04	1.25E-03	2.00E-03	ATSDR Chronic MRL EPA Chronic RfD
2,6-DNT	0.99	2.83E-05	1.49E-04	4.00E-03	ATSDR Intermediate MRL
Sum DNT	9.3	2.66E-04	1.40E-03		*

µg/L = microgram per liter
mg/kg/d = milligram per kilogram per day
* Comparison values for the sum of DNT nitrocompounds have not been published

Cancer Concerns Associated With Exposure to Nitrocompounds

Table 7.

Summary of Studies Describing Cancer Associated With Exposure to TNT

Study Type	Impact/Implications Related to Cancer
Animal	Mouse cellular studies suggest TNT may be a liver carcinogen (Styles and Cross 1983). Rats exposed to high concentrations of TNT in their diet had a higher incidence of urinary bladder cancer; however, these cancers were not identified in rats ingesting up to 2 mg/kg/d of TNT (Army 1984a, in ATSDR 1995). Mice ingesting 1.5 mg/kg/d of TNT had a statistically insignificant increase in leukemia and/or malignant lymphoma of the spleen (Army 1984b, in ATSDR 1995). *Potential exposure of residents, even residents using well water with the highest measured TNT concentration, is thousands of times less than the exposure in these animal studies.*
Human Occupational Exposure	An increase in liver cancer was identified in workers with high exposures to TNT (Yan et al 2002). Occupationally exposed male workers with a long history of heavy drinking were more likely to have signs of chronic liver impairment than those who did not drink (Li et al 1991). However, in both studies, the actual TNT exposure was not identified. A literature review describing the correlation between occupational exposures to TNT in the air and adverse health effects suggests a work-place concentration of 0.5 mg/m^3 of TNT for an 8-hr work day would be protective of worker health (Hathaway 1977). Some workers occupationally exposed to high concentrations of TNT in air (3.25 mg/m^3) for an 8-hr work day reported symptoms of bitter taste, and discolored skin and hair (Letzel et al 2003). *While occupational exposures are primarily by inhalation and not by ingestion, these results indicate that adverse health effects are not expected for low-dose exposures similar to those estimated for residents using well water with even the highest measured TNT concentration.*
Human Environmental Exposure	One study indicated a community near a German World War II era TNT plant experienced a slight increase in leukemia; however, there was little information about the level of TNT or other chemicals in the environment (Kolb et al 1993, in ATSDR 1995). Further study of the community indicates that although significant environmental contamination was released to the soil and streams during the TNT-production years (1937–1945) and during the uncontrolled destruction of the production plant, residents living in that area using groundwater or eating homegrown vegetables did not have a higher incidence of leukemia (Killian et al 2001).

Table 8.

Summary of Studies Describing Cancer Associated With Exposure to DNT

Study Type	Impact/Implications Related to Cancer
Animal	Mice ingesting either 2,4-DNT, 2,6-DNT or a DNT mixture did not experience an increase in lung tumor response (Schut et al 1983; Stoner et al 1984). Studies comparing the toxicity of 2,4-DNT to 2,6-DNT indicate that 2,6-DNT is primarily responsible for the carcinogenic activity of a DNT mix (Leonard et al 1983 and 1986, and Mirsalis and Butterworth 1982, in ATSDR 1998). In some studies, some animals ingesting large concentrations of DNT daily showed signs of hepatocellular carcinoma (a form of liver cancer). However, hepatocellular carcinoma was not identified in animals ingesting lower doses of DNT (0.7 mg/kg/d for 2,6-DNT to 22 mg/kg/d for 2,4-DNT (Ellis et al 1979, Leonard et al 1987, and Hazleton Laboratories 1982, in ATSDR 1998). Possible signs of liver carcinogenicity were found in male rats ingesting 0.6 to 3.5 mg/kg/d of 2,6-DNT with their normal diet for 1 year. The actual signs of liver cancer were vague and dependent on the other components of the animal's diet (Goldsworthy et al 1986). *These exposures are thousands of times greater than those estimated for residents using well water with the maximum measured concentrations of DNT.*
Human Occupational Exposure	One study indicated copper miners with very high exposures to technical grade DNT had a slight increase in cancer of the urinary track. The occupational exposure times varied from 7 to 37 years (Bruning et al 1999). However, the study size was rather small (500 miners), and the potential for other factors to influence the outcomes (other mining materials/exposures) was not discussed. *These exposures were for significantly longer time periods than those of the residents using well water. The occupational conditions of the exposure also suggest that the miners were exposed primarily by inhalation. It is expected that the occupational exposures would be much greater than those predicted for residents using well water with the maximum measured concentrations of DNT.*

Theoretical Increase of Cancer Concerns From Estimated Nitrocompound Ingestion

$$\text{Risk} = (\text{Ingestion} \times \text{CSF} \times \text{ED})/(70 \text{ yr})$$

Where:

Ingestion = Estimated daily ingestion of nitrocompound (mg/kg/d)

CSF = EPA's cancer slope factor for the nitrocompound $(\text{mg/kg-d})^{-1}$

ED = Exposure duration (yr)

70 yr = Risk averaged over an assumed 70-year lifetime

Table 9.

Theoretical Increase of Cancer Concerns Associated With Ingestion of Nitrocompounds*

	Estimated Ingestion Rate (Adult) (mg/kg/d)	Cancer Slope Factor† [$(\text{mg/kg/d})^{-1}$]	Exposure Duration (yr)	Exposure Duration (yr)	Theoretical Risk of Increased Cancer*
TNT	6.86E-05	0.03	2	70	5.9 E-08§
2,4-DNT	2.37E-04	NA‡			NA‡
2,6-DNT	2.83E-05	NA‡			NA‡
Sum DNT	2.66E-04	0.68	2	70	5.2 E-06§

* The theoretical risk of increased cancer represents the estimated increased probability of an individual developing cancer during their lifetime as a result of exposure to a chemical (EPA 1989). In comparison, recent data indicates the lifetime risk of an individual developing cancer is approximately 45% for men and 38% for women. The lifetime risk of an individual developing leukemia or cancer of the liver or urinary track ranges between 0.88% and 3.6% (Ries et al 2004).

† A cancer slope factor is a conservative estimate of the probability of a cancer response following lifetime exposure to a particular concentration of a potential carcinogen (EPA 1989).

‡ Cancer slope factors for individual DNT nitrocompounds have not been published.

§ The estimated theoretical risk of increased cancer is very low and could be zero.

Estimated Ingestion of Nitrocompounds From Swimming

$$\text{Ingestion} = (C \times IR \times EF \times ED) / (BW \times AT)$$

Ingestion = Ingestion rate of the nitrocompound (mg/kg/d)

C = Concentration of nitrocompound in swimming pool water (mg/L)

IR = Intake rate of swimming pool water (L/d)

EF = Exposure frequency (d/yr)

ED = Exposure duration (yr)

BW = Body weight (kg)

AT = Averaging time for exposure period (AT = ED × 365 d/yr) (d)

Table 10.

Summary of Input Values to Estimate Nitrocompound Ingestion From Swimming

Input Values	Adult	Child
IR (L/d)	0.3	0.3
EF (d)	183	183
ED (yr)	70	10
BW (kg)	70	10
AT (d)	25,550	3,650

Table 11.

Estimated Ingestion of Nitrocompounds From Swimming in Water Containing the Maximum Nitrocompound Concentration Measured in Residential Wells

	Maximum Concentration* (μg/L)	Estimated Ingestion Rate (Adult) (mg/kg/d)	Estimated Ingestion Rate (Child) (mg/kg/L)
TNT	2.4	5.16E-06	3.61E-05
2,4-DNT	8.3	1.78E-05	1.25E-04
2,6-DNT	0.99	2.13E-06	1.49E-05
Sum DNT	9.3	2.00E-05	1.40E-04
* Maximum concentration considering all wells			

Table 12.

Comparison of Estimated Nitrocompound Ingestion to ATSDR's Health Guidelines

	Maximum Concentration (µg/L)	Estimated Ingestion Rate (Adult) (mg/kg/d)	Estimated Ingestion Rate (Child) (mg/kg/L)	Comparison Value (mg/kg/d)	Comparison Value Source
TNT	2.4	5.16E-06	3.61E-05	5.00E-04	ATSDR Intermediate MRL EPA Chronic RfD
2,4-DNT	8.3	1.78E-05	1.25E-04	2.00E-03	ATSDR Chronic MRL EPA Chronic RfD
2,6-DNT	0.99	2.13E-06	1.49E-05	4.00E-03	ATSDR Intermediate MRL
Sum DNT	9.3	2.00E-05	1.40E-04		*

* Comparison values for the sum of DNT nitrocompounds have not been published.

Estimated Volume of Water Infiltrating Around a Root Vegetable

$V_{total} = (L \times A) = (L \times [\Pi R^2 - \Pi r^2])$

$V_{infiltrating\ water} = .3 \times V_{total}$

$V_{water} = (N \times V_{infiltrating\ water})$

V_{total} = Total volume of soil and pore space around the length of the root vegetable

L = Length of the root vegetable

A = cylindrical area around the length of the root

R = Radius to the farthest edge of the infiltrating water volume that will transport nitrocompounds to the root

r = Radius to the outside edge of the root

$V_{infiltrating\ water}$ = Volume of the infiltrating water that will transport nitrocompounds to the root during each irrigation; assume the soil has a porosity of approximately 30%

V_{water} = Total volume of water that will transport nitrocompounds to the root

N = Number of irrigation events during the growing season

Table 13.

Summary of Input Values and Results of Estimated Volume of Infiltrating Water

	Input Values
L (cm)	20
R (cm)	4.5
r (cm)	1.5
V_{total} (L)	1.13
$V_{infiltrating\ water}$ (L)	0.34
N	8
V_{water} (L)	2.7

Estimated Concentration of Nitrocompounds in a Root Vegetable

C_{root} = Concentration of nitrocompound in root
This concentration is derived from the following formula: $(C_{water} \times V_{water})/(M_{root})$
Where

C_{water} = Maximum concentration of nitrocompounds measured in wells
V_{water} = Total volume of water that will transport nitrocompounds to the root (Table 13)
M_{root} = Mass of root

Table 14.
Input Values and Estimated Nitrocompound Concentration in Root

	C_{water} (µg/L)	V_{water} (L)	M_{root} (g)	C_{root} (mg/kg)
TNT	2.4	2.7	100	0.065
2,4-DNT	8.3	2.7	100	0.22
2,6-DNT	0.99	2.7	100	0.027
Sum DNT	9.3	2.7	100	0.25

Estimated Ingestion of Nitrocompounds From Root Vegetables

Ingestion = (C_{root} × IR × EF × ED) / (BW × AT)

Ingestion = Ingestion rate of the nitrocompound (mg/kg/d)
C_{root} = Concentration of nitrocompound in the root (mg/kg)
IR = Daily vegetable intake rate (g/d)
EF = Exposure frequency (based on daily consumption for 4 months/yr) (d/yr)
ED = Exposure duration (yr)
BW = Body weight (kg)
AT = Averaging time for exposure period (AT = ED × 365 d/yr) (d)

Table 15.
Summary of Input Values to Estimate Nitrocompound Ingestion from Vegetable Consumption

Input Values	Adult	Child
IR (g/d)	300	150
EF (d/yr)	120	120
ED (yr)	70	10
BW (kg)	70	10
AT (d)	25,550	3,650

Table 16.
Summary of Estimated Nitrocompound Ingestion From Vegetable Consumption

	Estimated Concentration in Vegetable Root (µg/g)	Estimated Ingestion Rate (Adult) (mg/kg/d)	Estimated Ingestion Rate (Child) (mg/kg/d)
TNT	0.065	9.2E-05	3.2E-04
2,4-DNT	0.22	3.1E-04	1.1E-03
2,6-DNT	0.027	3.8E-05	1.3E-04
Sum DNT	0.25	3.5E-04	1.2E-03

Table 17.

Comparison of Estimated Nitrocompound Ingestion to ATSDR's Health Guidelines

	Estimated Concentration in Root (µg/g)	Estimated Ingestion Rate (Adult) (mg/kg/d)	Estimated Ingestion Rate (Child) (mg/kg/d)	Comparison Value (mg/kg/d)	Comparison Value Source
TNT	0.065	9.2E-05	3.2E-04	5.00E-04	ATSDR Intermediate MRL EPA Chronic RfD
2,4-DNT	0.22	3.1E-04	1.1E-03	2.00E-03	ATSDR Chronic MRL EPA Chronic RfD
2,6-DNT	0.027	3.8E-05	1.3E-04	4.00E-03	ATSDR Intermediate MRL
Sum DNT	0.25	3.5E-04	1.2E-03		NA*
* Comparison values for the sum of DNT nitrocompounds have not been published					

Estimated Ingestion by Horses of Nitrocompounds in Drinking Water

Ingestion = (C × IR × EF × ED) / (BW × AT)

Ingestion = Ingestion rate of the nitrocompound (mg/kg/d)
C = Concentration of nitrocompounds in drinking water (mg/L)
IR = Daily drinking water intake rate (L/d)
EF = Exposure frequency (d/yr)
ED = Exposure duration (yr)
BW = Body weight (kg)
AT = Averaging time for exposure period (AT = ED × 365 d/yr) (d)

Table 18.

Summary of Input Values to Estimate Nitrocompound Ingestion from Drinking Water by Horses

Input Values	Horse
IR (L/d)	38 (~ 10 gal/d)
EF (d)	365
ED (yr)	30
BW (kg)	540 (~ 1,220 lb)
AT (d)	10,950

Table 19.

Summary of Estimated Nitrocompound Ingestion by Horses From Drinking Water Containing Maximum Nitrocompound Concentration Measured in Residential Wells

	Maximum Concentration* (µg/L)	Estimated Ingestion Rate (Horse) (mg/kg/d)
TNT	2.4	1.7E-04
2,4-DNT	8.3	5.8E-04
2,6-DNT	0.99	7.0E-05
Sum DNT	9.3	6.5E-04
* Maximum measured concentration in residential wells		