

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Tetryl is a synthetic compound that does not occur naturally. It was once widely used as a military explosive but is no longer manufactured or used in the United States (see Chapter 4). Effluents and emissions from Army ammunition plants were responsible for the release of tetryl into the environment. When released to the atmosphere, tetryl is expected to react and undergo transformation with sunlight and it will be removed from the atmosphere by wet and dry deposition. When released to water, tetryl is subjected to hydrolysis and photolysis, but photolysis will be more important in surface water. Hydrolysis and photolysis products include picrate ion, N-methylpicramide, methylnitramine, nitrite ion, and nitrate ion. Tetryl is not mobile in soil and leaching into groundwater is not likely. Biodegradation studies suggest that tetryl may undergo biotransformation under certain environmental conditions.

The general population is not likely to be exposed to tetryl. During World War I and World War II, occupational exposure to tetryl was confined to workers in munition plants. For these workers, exposure occurred primarily by inhalation of tetryl-laden dusts, although some dermal and oral exposure probably occurred. Current exposure to tetryl is likely limited to areas around military installations, such as Army ammunition plants, where it was manufactured, converted to munitions, packed, loaded, or released through the demilitarization of antiquated munitions. The probable route of exposure for populations living near contaminated facilities or waste sites is ingestion of contaminated drinking water. Dermal exposure via contaminated water and soil may also occur. Occupational exposure to tetryl may occur in workers handling tetryl at Army ammunition plants during disposal operations.

Tetryl has been identified in 12 of the 1,397 hazardous waste sites on the NPL (HazDat 1994). The frequency of these sites within the United States can be seen in Figure 5-1.

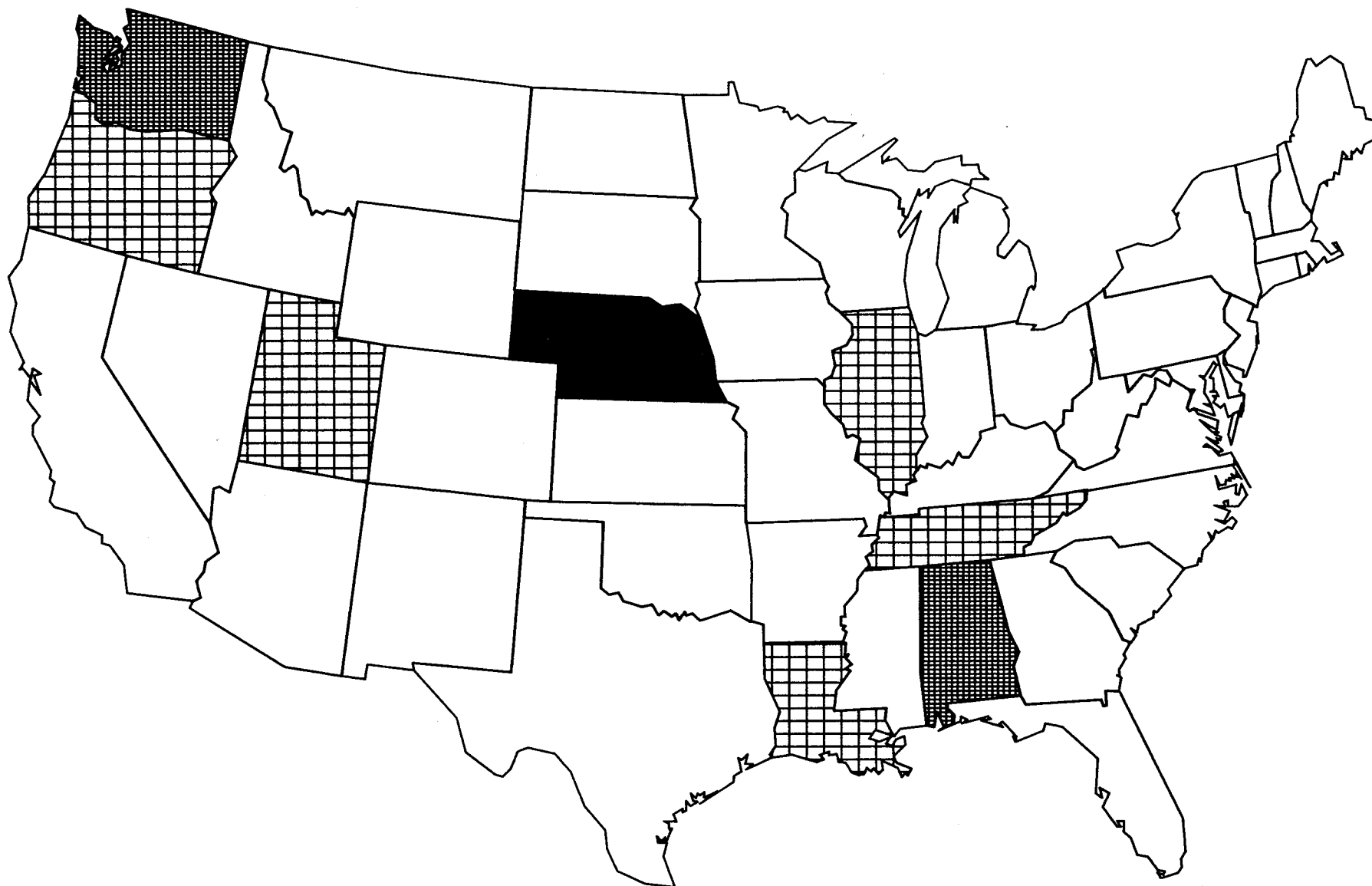
5.2 RELEASES TO THE ENVIRONMENT

Since tetryl releases are not required to be reported under SARA Section 313, there are no data on tetryl in the Toxics Release Inventory (TRI 1993).

FIGURE 5-1. FREQUENCY OF NPL SITES WITH TETRYL CONTAMINATION *

TETRYL

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FREQUENCY



1 SITE
3 SITES



2 SITES

*Derived from HazDat 1994

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5.2.1 Air

No data were located regarding releases of tetryl to air. A report on emissions from the Joliet Army Ammunition Plant (Joliet, Illinois), based on samples of effluent gases taken in 1967, showed only nitrogen oxides and sulfuric acid mist released to the air from the bubble tower and fume recovery facilities of tetryl manufacturing operations (Army 1976). Because tetryl is no longer manufactured or used in the United States, releases from these sources no longer occur. It is possible that some tetryl could be released to air during detonation, open-air burning, or incineration of the explosive during disposal operations (Army 1976, 1986b, 1986d). The by-products that have been reported to be produced when these methods are used include carbon monoxide, carbon dioxide, nitrogen oxides, nitrogen, water, and particulate carbon. The reported releases did not include tetryl, but it is unclear if tetryl was included in the analyses.

5.2.2 Water

Tetryl was released to water in waste discharge effluents from Army ammunition plants or through leaching from contaminated soil deposits. For example, the Joliet Army Ammunition Plant (Joliet, Illinois) produced tetryl until July 1973, releasing it via waste water into drainage ditches. Waste water streams discharged into drainage ditches typically containing 400,000-600,000 $\mu\text{g/L}$ tetryl, corresponding to a daily discharge of 769 pounds from the tetryl nitration and refining houses (Army 1976). Even after production of tetryl at the Army ammunition plant ceased, tetryl releases to surface water and groundwaters were still possible via runoff and leaching from contaminated soils at the plant site (Army 1974, 1976). A 1988 survey showed tetryl was present at a concentration of 67 $\mu\text{g/L}$ in a sample from a groundwater monitoring well installed in an area where highest soil contamination had been detected in 1981. However, tetryl was not detected in surface water, groundwater and sediment samples taken from other areas during 1981-1988 (detection limit of 1.8-100 $\mu\text{g/L}$ for surface water and 2.86 $\mu\text{g/L}$ for sediment) (Army 1990b). A monitoring study conducted at the ammunition plant during 1985-1986, detected tetryl in several groundwater samples at concentrations of 67 $\mu\text{g/L}$ in the tetryl production area, 34.5 $\mu\text{g/L}$ in the TNT production area, and 13.7 $\mu\text{g/L}$ in a waste water area (Army 1990b). The other possible sources of water contamination with tetryl are from runoff and leaching of the material at dump sites containing tetryl and at sites of demilitarization activities. No specific data on these potential sources were located.

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5.2.3 Soil

Tetryl was released to the soil in waste-discharge effluents from the manufacture of tetryl at Army ammunition plants and as a result of its use as an explosive (Army 1981b). Because tetryl is no longer manufactured or used in the United States (Army 1984c, 1989b), new releases from manufacturing sources will not occur. However, contamination from past releases may still exist. In addition, tetryl may be released to soil from demolition landfills or during demilitarization operations (open detonation or open burning) (Army 1981b, 1986b). Tetryl was detected at concentrations of <1,000 µg/gram in 4.8% of soil samples taken from open-burning grounds at selected military installations; none of the samples contained >1,000 µg tetryl/gram of soil (Army 1986b). In a 1981 survey of contamination at the Joliet Army Ammunition Plant (Joliet, Illinois), tetryl was found in two of five surface soil samples. Measured levels were 38,500 µg/gram in the surface soil near the tetryl production area and at a concentration 23.5 µg/gram in a location removed from this area. Tetryl was not detected in five soil core samples taken from the same area in 1988 (detection limit of 1.86µg/gram) (Army 1990b). No other specific data on releases to soil were located.

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

Neat tetryl is chemically stable and only slightly hygroscopic. It has remained stable for as long as 20 years during storage at ordinary temperatures (Bergman 1952). Although nitrated compounds are expected to exist in both the vapor phase and particulate form (Eisenreich et al. 1981), based on a vapor pressure of 4×10^{-10} mmHg (Army 1987d), it is unlikely that tetryl will partition to air. It is possible that tetryl might exist in the air as a particulate under certain conditions (i.e., following detonation or open-air burning), although no data were located. Tetryl present in the air as particulate would likely be deposited to land and water through wet and dry deposition. Tetryl is slightly soluble in water (75 mg/L in 20 °C fresh water; 26 mg/L in 25 °C salt water) (Army 1987d; Hoffsommer and Rosen 1973) but is soluble in alcohol, ether, benzene, acetone, and glacial acetic acid (Merck 1989). The calculated Henry's law constant for tetryl is 2.0×10^{-12} atm·m³/mol (Army 1987d). Based on this value of Henry's law constant, tetryl is considered essentially nonvolatile (Lyman et al. 1982); therefore, volatilization is not expected to be an important fate process.

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The mobility of tetryl through soil may be determined based on its K_{oc} value. A K_{oc} value of 406 has been calculated for tetryl based on a water solubility of 75 mg/L (HSDB 1994); however, a K_{oc} of 1,357-2,948 was estimated for tetryl based on measured water-soil partition coefficients (Army 1979, 1987d). The higher measured value may result from the binding of tetryl and its decomposition products to humic matter in soil (Army 1987d; Bongiovanni et al. 1984; Harvey et al. 1992). These higher K_{oc} values suggest that tetryl is slightly mobile in soil (Swarm et al. 1983); therefore, tetryl is not expected to leach substantially into groundwater, particularly if the soil has a high organic content. Monitoring studies have indicated that the movement of tetryl through soil to groundwater may be influenced by other factors. These factors include its rapid hydrolysis in soil which may, in some cases, prevent tetryl reaching the underlying groundwater (Kayser and Burlinson 1988). Alternatively, the presence of other solvents at contamination sites may increase the mobility of tetryl through the soil (Army 1974, 1990b). Tetryl has been detected in water collected in seepage holes and groundwater monitoring wells dug at contaminated soil sites, indicating some leaching does occur (Army 1974, 1990b).

The logarithm of the *n*-octanol/water partition coefficient ($\log K_{ow}$) is a useful preliminary indicator of potential bioaccumulation of a compound. The $\log K_{ow}$ for tetryl was calculated to be 2.4 (Army 1987d), indicating a low potential for bioaccumulation. The bioconcentration factor (BCF) for tetryl was calculated to be 54 from a recommended regression-derived equation (HSDB 1994; Lyman et al. 1982). This BCF value does not suggest a potential for significant bioconcentration in aquatic organisms (HSDB 1994). Using an alternate regression-derived equation, a BCF of 15 was calculated (Army 1987d), which supports the low bioaccumulation potential of tetryl. However, the estimated BCF value based on K_{ow} is highly uncertain since it does not adequately take in account the interaction of tetryl with protein and other compounds present in fish tissues. Partition coefficients for plant/soil and beef fat/diet of 1 and 3.7×10^{-3} , respectively, were also calculated (Army 1987d). However, during attempts to develop a method of analyzing for tetryl in biological tissues (animal plasma, kidney, muscle/fat, and liver, as well as plant stems), tetryl could not be extracted from the samples even when intentionally spiked (Army 1981a). The authors concluded that tetryl was irreversibly adsorbed to macromolecules in the plant and animal tissues by binding of the methylnitroamino group (Army 1981a). The impact of macromolecular binding on the bioconcentration of tetryl in aquatic and terrestrial organisms is not known. No experimental bioconcentration data were located.

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In a plant uptake study with bush bean plants maintained on tetryl-amended hydroponic cultures for exposure periods of up to 7 days, all but a small amount (3%) of tetryl was rapidly converted to polar metabolites. The majority of the tetryl metabolites (89% to 96%) were located within the root tissues. An intermediate amount of metabolites (3%-7%) was found in the stem tissues; the leaf tissues contained the smallest quantity (1%-4%) (Harvey et al. 1993).

Picric acid, one of the breakdown products of tetryl, is soluble in water and is expected to leach through soil to groundwater in substantial amounts (Army 1987d). It is expected to dissociate in water, especially when present in low concentrations. Picric acid may also form complexes with metal ions in soil, causing some of the chemical to remain bound (Army 1987d). Picric acid that is bound to soil may be transformed via photolysis if present at the soil surface (Army 1987d).

5.3.2 Transformation and Degradation

5.3.2.1 Air

Tetryl (vapor phase) in the air may react with photochemically formed hydroxyl radicals. The half-life for this reaction was estimated to be $\gg 10$ days assuming a normal atmospheric concentration of 5×10^5 hydroxyl radicals per cm^3 and a gas phase reaction rate of $\ll 1 \times 10^{-12} \text{cm}^3/\text{molecule-second}$ (Atkinson 1987; HSDB 1994). However, because tetryl has a very low vapor pressure and Henry's law constant (see Table 3-2), only a small amount of tetryl is expected to exist in the atmosphere in the vapor phase (Eisenreich et al. 1981) and be available for transformation via reaction with hydroxyl radicals. In the atmosphere, tetryl is expected to be more prevalent in the particulate form. The hydroxyl radical reaction rate for particulate tetryl would be much slower than the vapor phase reaction rate. Therefore, the transformation of tetryl in air due to reaction with OH radicals may not be important. No data were located on direct photolysis of tetryl in the atmosphere, but tetryl is expected to undergo direct photolytic degradation in the atmosphere because it undergoes this reaction in water (Army 1984d). Based on a pure water photolysis half-life of 20-40 hours for TNT, a structurally similar compound (Mabey et al. 1983), it is likely that photolysis will dominate the degradative fate of tetryl in air.

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5.3.2.2 Water

If released to water, tetryl may be degraded by hydrolysis. Based on experimentally-derived pH (range of 4-9) versus rate profiles for tetryl at 40, 72, and 85 °C and a range of activation energies, the hydrolysis half-life of tetryl at 20 °C and pH 6.8 was crudely estimated to be 302 ± 76 days. Since the estimated half-life has a maximum uncertainty factor of 3, the hydrolysis half-life at 20 °C and pH 6.8 may be as high as 900 days. The hydrolysis rate is expected to increase with increasing temperature and pH (Navy 1984b). Hydrolysis products include picrate ion, N-methylpicramide, methylnitramine, nitrite ion, and nitrate ion. In the dark and under buffered, alkaline conditions (pH 9), methylnitramine formation dominated (66%); picrate ion (28%), nitrite (4.1%), nitrate (3.1%), and N-methylpicramide (4.1%) were also formed. Under laboratory light and more acidic conditions (pH 4-6), N-methylpicramide (41%) and nitrate (35.2%) were the major products; picrate ion (3.9%), nitrite (9.4%), and methylnitramine (0.01%) were also formed (Navy 1984b). In sea water at 25 °C and pH 8.1, 88% of initial tetryl hydrolyzed in 101 days, yielding picric acid as a hydrolysis product. This hydrolysis rate corresponds to a first-order half-life of 33 days (Hoffsommer and Rosen 1973; HSDB 1994).

Under ambient lighting conditions and pH 6, the photolysis rate has been observed to be at least an order of magnitude faster than hydrolysis, with a hydrolysis half-life of approximately 302 days (Navy 1984b). After 20 minutes of incubation in the light, more than 95% of the initial concentration of tetryl (1-20 mg/L) had reacted, but only 3.2% had reacted in the dark. Therefore, photolysis may be the dominant degradation process in sunlit water (Navy 1984b). The photolysis study of a structurally similar compound (TNT) conducted by Mabey et al. (1983) tends to confirm this conclusion. The major detectable photolytic product of tetryl in aqueous solution was reported to be N-methylpicramide (Navy 1984b).

Insufficient data are available to predict the relative importance of biodegradation in water.

5.3.2.3 Soil

Based on effects observed in water (Navy 1984b), tetryl released to soil is expected to be susceptible to slow hydrolysis in acidic and neutral soils and to relatively rapid hydrolysis in highly alkaline soils (HSDB 1994). Samples of water collected from lysimeters containing tetryl-contaminated soil

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indicated that the major transformation products were picric acid (5-14%) and other polar, watersoluble decomposition products; no tetryl was detected in the water, or in the soil at the end of the study, suggesting complete hydrolysis (Kayser and Burlinson 1988; Navy 1982). The specific reaction leading to these products was not determined. Because tetryl is subject to photolysis in water, it may be susceptible to photolysis on sunlit soil surfaces (HSDB 1994).

Data from composting experiments suggest that biodegradation of tetryl may occur under some conditions (Army 1986a). When tetryl-contaminated sediment was added to hay-horse feed or sewage sludge-wood chip compost, 90% of the tetryl was removed after 44 days. A first-order half-life of 1.2 weeks was calculated for tetryl in a manure-hay-sawdust compost. In a biodegradation study with two types of soils (silt-loam and sandy loam), tetryl was found to undergo rapid biotransformation via two principal pathways (Harvey et al. 1992). The principal product of biodegradation was identified as N-methyl-2,4,6-trinitroaniline. Aminodinitrophenylmethyl nitramine and other unidentified polar metabolites were identified as secondary biodegradation products. Mineralization of tetryl to carbon dioxide accounted for 9% of total degradation over a 60-day incubation period. However, the authors did not provide conclusive evidence that the primary degradation product N-methyl-2,4,6-trinitroaniline was not an artifact of methanolic Soxhlet extraction of soil. This may cast doubt on the validity of the conclusions of this soil biodegradation study (Jenkins and Walsh 1994).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

No data were located regarding the levels of tetryl in air.

5.4.2 Water

Seepage water collected in a hole dug at the Joliet Army Ammunition Plant (Joliet, Illinois) in August 1973 contained tetryl at a concentration of 44,000 µg/L (Army 1974, 1990b). Later surveys conducted between 1985 and 1986 showed tetryl was present in groundwater samples taken from monitoring wells around the plant site; it was detected at 67 µg/L in a sample from the tetryl production area, at 34.5 µg/L in samples from the TNT production area, and at 13.7 µg/L in a waste water area (Army 1990b). The groundwater beneath the tetryl manufacturing area of the Alabama Army Ammunition

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Plant (Talladega County, Alabama) contained 72.8 µg/L tetryl (ATSDR 1987). Tetryl has been detected in groundwater beneath artificial leaching pits located at the Louisiana Army Ammunition Plant at concentrations ranging from 1.4 to 53 µg /L (Army 1988).

No tetryl was detected (detection limit of 20 µg /L) in samples from 44 groundwater sites, 23 surface water sites, or 5 treatment lagoons located at the Milan Army Ammunition Plant in Tennessee (Army 1980). In addition, sediment samples from the 5 lagoons did not show tetryl to be present (detection limit of 90 µg /L). Tetryl was detected in groundwater samples taken at the Iowa Army Ammunition Plant at a maximum concentration of 49 µg /L; it did not exceed the level of detection (2.9 µg /L) in any surface water samples (Army 1982c).

Sea water samples taken in 1971 from two munitions dumping areas (at depths of 0-20 meters above the bottom and at the centers of the dumping areas) located in the Pacific Ocean (85 miles west of Cape Flattery, Washington) and the Atlantic Ocean (172 miles south-southeast of Charleston, South Carolina) were analyzed for tetryl (Navy 1972). No tetryl was found in any of the samples examined (detection limit of 20 ng/L).

5.4.3 Soil

Analysis of surface soil collected from the Joliet Army Ammunition Plant (Illinois) from 1973 to 1981 showed tetryl levels ranging from 23.5 to 84,400 µg /gram. Analysis of subsurface soil detected levels of 1,450-84,400 µg /gram tetryl. It was estimated that the soil at the Joliet Army Ammunition Plant (Illinois) contained approximately 31,000 pounds of tetryl in August 1973, less than 1 month after tetryl production had been terminated (Army 1974, 1990b). In a 1981 survey of contamination at the Joliet Army Ammunition Plant (Joliet, Illinois), tetryl was found in 2 of 5 samples from the tetryl production area at levels of 23.5-38,500 µg /gram in an old drainage ditch and in a location removed from the ditch, but none was detected in 5 soil samples taken from the same area in 1988 (detection limit of 2.86 µg /gram) (Army 1990b). One of 49 surface soil samples collected from 11 sites at the Milan Army Ammunition Plant (Milan, Tennessee) contained approximately 1.8 µg /gram of tetryl (Army 1980).

At the Louisiana Army Ammunition Plant (a shell manufacturing and explosives loading, assembly, and packing facility near Shreveport, Louisiana), waste waters were trucked to and discharged into on-

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site artificial leaching pits from 1951 to 1980 (Army 1986a, 1988). Tetryl in surface soil samples taken from the lagoons in 1984 ranged from below detectable levels (detection limit of 0.3 µg /gram) to 42,217 µg /gram, while tetryl concentrations in the underlying soil cores ranged from below the detection limit to 7,113 µg /gram.

At the Alabama Army Ammunition Plant, tetryl was measured in the soil of the tetryl manufacturing area (13,600 µg /gram) and in the flashing ground (for flash burning of equipment and demolition materials to remove explosive residues) (6,620 ppm) (ATSDR 1987). At the same site, tetryl levels were also reported as <257-6,624 ppb in the flashing ground, >500 ppb in the rifle powder flashing area, and 554 ppb in the demolition landfill (Army 1981b). In the tetryl manufacturing area, a crystalline material suspected of being tetryl was visible in the soil.

Tetryl was detected in sediment samples taken at the Iowa Army Ammunition Plant at a maximum concentration of 33 µg /gram (Army 1982c). However, all soil samples were below the level of detection (2 µg /gram).

Ocean floor sediment samples taken in 1971 from two munitions dumping areas located in the Pacific Ocean (85 miles west of Cape Flattery, Washington) and the Atlantic Ocean (172 miles southsoutheast of Charleston, South Carolina) were analyzed for tetryl (Navy 1972). No tetryl was found in any of the sediment samples analyzed (no detection limit reported).

5.4.4 Other Environmental Media

Samples from ocean floor fauna (rat tail fish and sea cucumbers) taken in 1971 from two munitions dumping areas located in the Pacific Ocean (85 miles west of Cape Flattery, Washington) and the Atlantic Ocean (172 miles south-southeast of Charleston, South Carolina) were analyzed for tetryl (Navy 1972). No tetryl was found in any of the fauna samples analyzed (detection limit of 740 ppt).

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The general population is not likely to be exposed to tetryl. Exposure to tetryl is likely to be limited to areas around military installations, such as Army ammunition plants (where tetryl was manufactured and converted to munitions), around storage and waste sites, and around sites of demilitarization and

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disposal operations. The most likely route of exposure for populations living near these areas is ingestion of contaminated drinking water. However, no data regarding estimated daily intakes of tetryl through drinking water were found for such populations. Inhalation of contaminated particulate matter produced during incineration, open-air burning, and detonation of tetryl-containing waste material is a possible route of exposure. However, since no monitoring data were located regarding levels of tetryl in air, the extent of exposure by this route is not known. Dermal contact with contaminated soil is also a possible route of exposure. However, no data concerning extent of absorption following dermal contact with tetryl-contaminated soil were located.

Inhalation, dermal, and some oral exposure to tetryl has occurred in workers involved in production and use of tetryl compounds. In the past, workers in munitions plants were exposed to tetryl dust released into workroom air (Cripps 1917; Hardy and Maloof 1950; Hilton and Swanston 1941; Probst et al. 1944; Troup 1946; Witkowski et al. 1942). In one study, air samples taken in 1942 from a small powder house where exploder bags were loaded with weighted tetryl, stemmed, tied, and inspected had tetryl levels ranging from 1 to 18 mg/m³ (Hardy and Maloof 1950). Workers in these plants were exposed via inhalation of the tetryl dust and by dermal contact with the tetryl powder and pellets. Today, workers engaged in demilitarization operations involving detonation, open-burning, or incineration of tetryl explosives are likely to be exposed to tetryl. The extent of exposure in these workers has not been adequately determined.

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers who were involved in the production and use of tetryl at Army ammunition plants were exposed to tetryl. Persons living near military installations, such as Army ammunition plants, may be exposed to tetryl from ingestion of drinking water or contact with soil contaminated by past manufacture and use. Persons involved in demilitarization operations or in the clean-up of contaminated sites may be exposed to high levels of tetryl.

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of tetryl is available. Where adequate information is not

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available, ATSDR, in conjunction with NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of tetryl.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that, if met, would reduce or eliminate the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda may be proposed.

5.7.1 Identification of Data Needs

Physical and Chemical Properties. The physical and chemical properties of tetryl as shown in Table 3-2 are not sufficiently characterized to permit estimation of its environmental fate (Army 1987d; HSDB 1994; Navy 1984b). It would be helpful to develop experimental K_{ow} and K_{oc} data for tetryl.

Production, Import/Export, Use, and Release and Disposal. Tetryl is no longer produced in the United States (Army 1984c, 1989b). Production in the United States was limited to Army ammunition plants such as the Joliet Army Ammunition Plant (Illinois), which produced tetryl until 1973 (HSDB 1994). Several other Army ammunition plants that have handled tetryl in the past include Anniston (Alabama), Crane (Indiana), Fort Wingate (New Mexico), Hawthorne (Nevada), Letterkenny (Pennsylvania), Lexington (Kentucky), Louisiana (Louisiana), McAlester (Oklahoma), Milan (Tennessee), Navajo (Arizona), Pine Bluff (Arkansas), Pueblo (Colorado), Red River (Texas), Savanna (Illinois), Seneca (New York), Sierra (California), Tooele (Utah), and Umatilla (Oregon) (Army 1986a, 1986b). Past production and import/export data for tetryl were not available. Tetryl has primarily been used as an explosive (Gibbs and Popolato 1980; HSDB 1994), although it has also been used as a chemical indicator in the pH range between 10.8 and 13.0 (Merck 1989). Tetryl was primarily released to soil, surface water, and groundwater around military installations, such as Army ammunition plants (Army 1974, 1981b, 1987b, 1988; ATSDR 1987), and contamination still remains in some of these areas. Current releases probably occur at waste sites where tetryl is stored and at sites of demilitarization activities. More data on possible releases from these sources are needed in

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order to better determine populations at risk of exposure to tetryl. Data on the most commonly used disposal methods are sufficient (Army 1986b, 1986d, 1987a); however, more data on amounts of tetryl being disposed of and on alternative disposal methods would be useful. Wastes generated in the manufacturing of tetryl are classified as EPA hazardous wastes and must be disposed of according to EPA regulations (EPA 1990b).

Environmental Fate. Tetryl released to the environment partitions mainly to water and soil (Army 1987d; Lyman et al. 1982; Navy 1984b). Tetryl is transported in soil, surface water, and, rarely, in groundwater (Army 1987d; Swann et al. 1983). Because of its very low vapor pressure, it is unlikely to partition to air (Army 1987d). No data were located regarding atmospheric transport of tetryl. Experimental data are needed regarding photolysis of tetryl in the atmosphere so that the relative contributions of photochemical degradation can be determined. Photolysis and hydrolysis are the primary mechanisms that degrade tetryl in water (HSDB 1994). It would be helpful to develop reliable data for photoreaction, hydrolysis and biodegradation rates of tetryl in natural water, and biodegradation rates of tetryl in natural soils.

Data on the rates of biodegradation, photolysis and hydrolysis of tetryl in natural waters and the rate of biodegradation of tetryl in natural soil would help to estimate more accurately the persistence of tetryl in the environment. Additional data on the nature and fate of transformation products of tetryl in air, water, and soil are also needed.

Bioavailability from Environmental Media. Indirect evidence for absorption of tetryl is provided by the adverse health effects observed in exposed workers (Cripps 1917; Hardy and Maloof 1950; Hilton and Swanston 1941; Troup 1946; Witkowski et al. 1942). However, the relative contribution by the three possible routes (inhalation, oral, and dermal) is not known. Rabbits fed tetryl excreted picramic acid, a metabolite of tetryl, in their urine, showing that tetryl is absorbed following ingestion (Zambrano and Mandovano 1956). The oral and dermal routes of exposure, in particular, may be of concern to humans because of the potential for tetryl to contaminate drinking water and soil. Information regarding absorption of tetryl following ingestion of contaminated drinking water and dermal contact with contaminated water or soil would be useful in characterizing the bioavailability of tetryl from these media.

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Food Chain Bioaccumulation. Since tetryl is likely to be bound strongly to fish tissues, the estimated BCF values based on K_{ow} (Army 1987d; HSDB 1994; Lyman et al. 1982) is likely to be questionable. Therefore, it would be useful to develop experimental data for BCF in aquatic organisms. Based on estimated plant-soil and beef fat-diet partition coefficients, bioaccumulation in plants and animals is expected to be low (Army 1987d). However, data exist to suggest that tetryl may bind to macromolecules in plant and animal tissues (Army 1981a), implying that bioconcentration is possible. No experimental data were located that would support either possibility. Experimental data are needed regarding the biomagnification potential of tetryl in both aquatic and terrestrial food chains. Primary emphasis needs to be given to development of a method that will enable tetryl to be extracted from plants and animal tissue. Metabolism data could also provide useful information that would help in determining the potential for bioaccumulation within organisms.

Exposure Levels in Environmental Media. Tetryl has been detected in seepage water, groundwater, and surface and subsurface soil at military installations (Army 1980, 1981b, 1986a, 1988, 1990b; ATSDR 1987; HazDat 1994). More data are needed regarding levels of tetryl in surface water, groundwater, soil, and air in and around these sites. Quantitative information is needed to assess the potential for human exposure and to better identify exposed populations.

Exposure Levels in Humans. Biomarkers for exposure to tetryl, especially metabolic products need to be identified so that biological monitoring studies can be conducted. Data are needed both for occupationally exposed populations and for populations living in the vicinity of Army ammunition plants and hazardous waste sites. These data would aid in evaluating the extent of human exposure.

Exposure Registries. No exposure registries for tetryl were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to the exposure to this substance.

5.7.2 Ongoing Studies

No ongoing studies on tetryl were located.