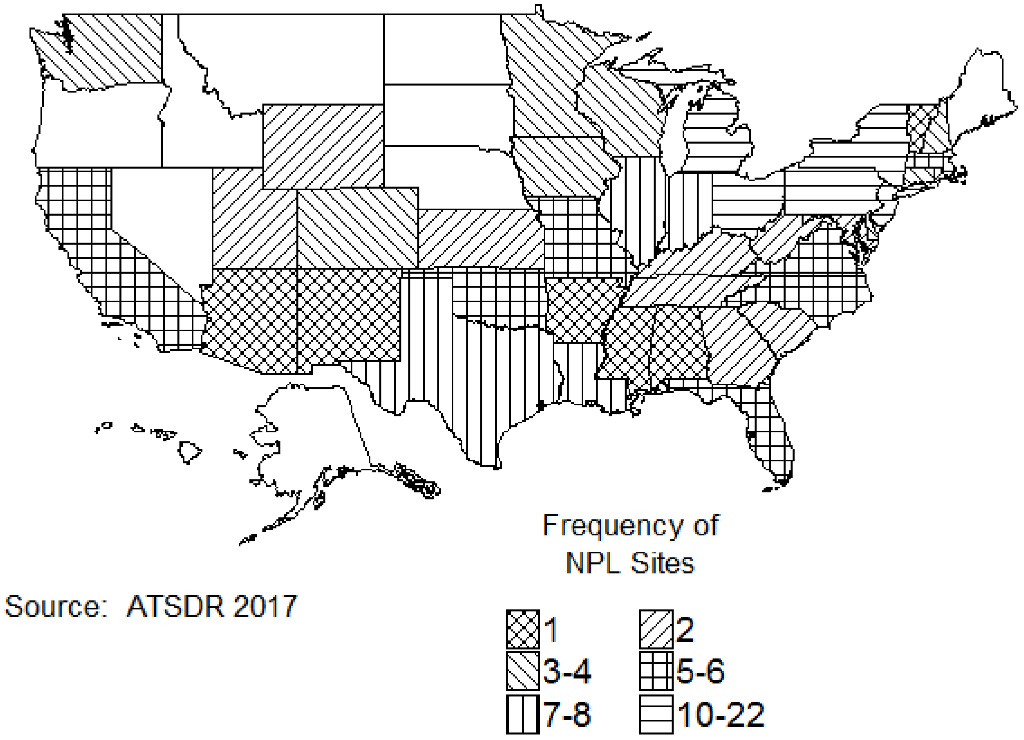
CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

N-Nitrosodiphenylamine has been identified in at least 199 of the 1,854 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2017). However, the number of sites in which *N*-nitrosodiphenylamine has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. The 199 sites are located within the United States.

Figure 5-1. Number of NPL Sites with *N*-Nitrosodiphenylamine Contamination



Source: ATSDR 2017

- *N*-Nitrosodiphenylamine has not been found in air, drinking water, or foods, so it is unlikely that the general public will be exposed to this chemical.

- Persons living near facilities producing, or waste sites containing, diphenylamine may have a higher risk of exposure to *N*-nitrosodiphenylamine via microbial production of the chemical.

- *N*-Nitrosodiphenylamine has been produced by reacting diphenylamine and sodium nitrite in water that has been acidified with sulfuric acid.

- *N*-Nitrosodiphenylamine is used as a vulcanization retardant in rubber compounds used to make tires.

- *N*-Nitrosodiphenylamine can be released to air from waste sites. In air, it is decomposed by sunlight. It also can react with other chemicals; the half-life for this reaction is 7 hours.
- In laboratory test, most *N*-nitrosodiphenylamine disappears from water and soil within several weeks.

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

N-Nitrosodiphenylamine is not known to occur naturally in the environment (IARC 1982a). However, there is evidence to indicate that microorganisms produce the chemical under laboratory conditions (Ayanaba and Alexander 1973). It is possible that this may take place under environmental conditions also. *N*-Nitrosodiphenylamine has been produced by reacting diphenylamine and sodium nitrite in water that has been acidified with sulfuric acid (NIOSH 1983). The *N*-nitrosodiphenylamine is then separated from the aqueous layer, drained, dried on hot rollers, and packed as the final product into drums.

N-Nitrosodiphenylamine had been produced commercially in the United States since 1945 (IARC 1982a). U.S. production volumes peaked in 1974 at 3.2 million pounds and gradually declined to 0.4 million pounds in 1980. The decline in production was due to the availability of new and more efficient chemicals for its applications in the rubber-processing industry (Taylor 1982). Production volumes are not available after 1980 (USITC 1985, 1986, 1987, 1988).

According to the Toxics Release Inventory (TRI), there is one facility in the United States that manufactured or processed *N*-nitrosodiphenylamine in 2016 (TRI16 2017). See Table 5-1 for more details. The data listed in the TRI should he used with caution since only certain types of facilities are required to report. This is not an exhaustive list.

Table 5-1. Facilities that Produce, Process, or Use *N*-Nitrosodiphenylamine

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
LA	1	10,000	99,999	2, 3, 10

[a]Post office state abbreviations used.
[b]Amounts on site reported by facilities in each state.
[c]Activities/Uses:

1. Produce
2. Import
3. Used Processing
4. Sale/Distribution
5. Byproduct
6. Reactant
7. Formulation Component
8. Article Component
9. Repackaging
10. Chemical Processing Aid
11. Manufacture Aid
12. Ancillary
13. Manufacture Impurity
14. Process Impurity

Source: TRI16 2017 (Data are from 2016)

5.2.2 Import/Export

Imports of *N*-nitrosodiphenylamine through principal U.S. customs districts increased from 52,000 pounds in 1977 to 110,000 pounds in 1982 (USITC 1978a, 1983). Current import and export data for *N*-nitrosodiphenylamine are not available.

5.2.3 Use

N-Nitrosodiphenylamine was primarily used as a retardant in the rubber-processing industry (HSDB 1990). Retardants are chemicals that prevent the premature vulcanization of rubber compounds during certain rubber-processing steps such as mixing and calendaring. *N*-Nitrosodiphenylamine was generally used with the sulfenamide accelerators in tire compounds. The use of *N*-nitrosodiphenylamine as a retardant had the following undesirable side effects: gaseous decomposition products of *N*-nitrosodiphenylamine during vulcanization cause porosity in thick cross-section extrusions; *N*-nitrosodiphenylamine is a nitrosating agent of secondary amines, which are suspected to be animal carcinogens; it is slightly staining; and it is not efficient in the presence of alkyl-atyl or dialkyl-substituted *p*-phenylenediamine antidegradants (Taylor 1982).

N-Nitrosodiphenylamine was also used as an intermediate in the manufacture of *p*-nitrosodiphenylamine. *p*-Nitrosodiphenylamine can be reduced to *N*-phenyl-*p*-phenylenediamine, which is also a rubber-processing chemical and an intermediate in the production of other rubber-processing chemicals (OHM/TADS 1990).

5.2.4 Disposal

Product residues and sorbent media containing *N*-nitrosodiphenylamine can be packaged in 17H epoxy-lined drums and disposed of at an EPA-approved site. The compound can be destroyed by high-temperature rotary kiln or fluidized bed incineration with scrubbing equipment (NO_X scrubber) or acid hydrolysis (HSDB 1990).

5.3 RELEASES TO THE ENVIRONMENT

The Toxics Release Inventory (TRI) data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ ≥10 full-time employees; if their facility is included in Standard Industrial Classification (SIC) Codes 10 (except 1011, 1081, and 1094), 12 (except 1241), 20–39, 4911 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4931 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4939 (limited to facilities that combust coal and/or oil for the purpose of generating electricity for distribution in commerce), 4953 (limited to facilities regulated under RCRA Subtitle C, 42 U.S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited S.C. section 6921 et seq.), 5169, 5171, and 7389 (limited to facilities primarily engaged in solvents recovery services on a contract or fee basis); and if their facility produces, imports, or processes ≥25,000 pounds of any TRI chemical or otherwise uses >10,000 pounds of a TRI chemical in a calendar year (EPA 2005).

5.3.1 Air

Estimated releases of 11 pounds of *N*-nitrosodiphenylamine to the atmosphere from one facility reporting to TRI) domestic manufacturing and processing facilities in 2016, accounted for 100% of the estimated total environmental releases from facilities required to report to the TRI (TRI16 2017). These releases are summarized in Table 5-2.

N-Nitrosodiphenylamine may he released to the atmosphere from sewage sludge incinerators (Gerstle 1988) or from hazardous waste sites. Release of *N*-nitrosodiphenylamine to the environment can occur from effluent discharges generated from its production and use.

Table 5-2. Releases to the Environment from Facilities that Produce, Process, or Use *N*-Nitrosodiphenylamine[a]

		Reported amounts released in pounds per year[b]							
							Total release		
State[c]	RF[d]	Air[e]	Water[f]	UI[g]	Land[h]	Other[i]	On-site[j]	Off-site[k]	On- and off-site
LA	1	11	0	0	0	0	11	0	11
Total	1	11	0	0	0	0	11	0	11

[a] The TRI data should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list. Data are rounded to nearest whole number.
[b] Data in TRI are maximum amounts released by each facility.
[c] Post office state abbreviations are used.
[d] Number of reporting facilities.
[e] The sum of fugitive and point source releases are included in releases to air by a given facility.
[f] Surface water discharges, waste water treatment-(metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).
[g] Class I wells, Class II-V wells, and underground injection.
[h] Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.
[i] Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown
[j] The sum of all releases of the chemical to air, land, water, and underground injection wells.
[k] Total amount of chemical transferred off-site, including to POTWs.

RF = reporting facilities; UI = underground injection

Source: TRI16 2017 (Data are from 2016)

5.3.2 Water

No releases of *N*-nitrosodiphenylamine to surface water or publicly owned treatment works (POTWs) were reported from facilities required to report to the TRI (TRI16 2017).

N-Nitrosodiphenylamine may be released in industrial waste water (Rhoades et al. 1980). There is also evidence suggesting that some microorganisms produce *N*-nitrosodiphenylamine from diphenylamine and nitrate or nitrite in the environment (Ayanaba and Alexander 1973). Although this has only been shown for pure cultures under laboratory conditions, it may be a natural source of *N*-nitrosodiphenylamine in the environment.

5.3.3 Soil

No releases of *N*-nitrosodiphenylamine to soils from were reported by facilities required to report to the TRI, and no *N*-nitrosodiphenylamine was released via underground injection (TRI16 2017).

There is evidence suggesting that *N*-nitrosodiphenylamine might be produced by some microorganisms under certain environmental conditions (Ayanaba and Alexander 1973).

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

Air. *N*-Nitrosodiphenylamine has a vapor pressure of 0.1 mmHg at 25°C (HSDB 1990). It should exist almost entirely in the vapor phase in the atmosphere (Eisenreich et al. 1981).

Water. *N*-Nitrosodiphenylamine is soluble in water (40 mg/L) (EPA 1982a). The Henry's law constant for *N*-nitrosodiphenylamine (6.6×10^{-4} atm-m^3/mol) (EPA 1982a) indicates that volatilization from water will be slow but significant transport process (Lyman et al. 1982).

Sediment and Soil. The soil sorption coefficient (K_{oc}) for *N*-nitrosodiphenylamine was estimated to range from 830 to 1,830 (Lyman et al. 1982). This K_{oc} range is indicative of low mobility in soil; therefore, significant leaching is not expected to occur in most types of soil (Swann et al. 1983). In the aquatic environment, substantial partitioning from the water column to sediment and suspended particulate organic matter may occur.

Other Media. The logarithm of n-octanol/water partition coefficient (log K_{ow}) is a useful preliminary indicator of potential bioaccumulation of a compound. The log K_{ow} for *N*-nitrosodiphenylamine was estimated to range from 2.57 to 3.13, indicating a low potential for bioaccumulation (Banerjee et al. 1980; Barrows et al. 1980). An experimental bioconcentration factor of 217 was determined for *N*-nitrosodiphenylamine based on a continuous 14-day exposure study of bluegill sunfish with a mean *N*-nitrosodiphenylamine water concentration of 9.21 ppb (Barrows et al. 1980). The half-life of *N*-nitrosodiphenylamine in the fish was found to be <1 day when the fish were placed in pollutant-free water after the exposure period. The relatively low experimental bioconcentration potential and short half-life of *N*-nitrosodiphenylamine indicate that biomagnification in the aquatic food chain is not a major environmental fate process (Barrows et al. 1980).

5.4.2 Transformation and Degradation

Air. *N*-Nitrosodiphenylamine absorbs sunlight, suggesting a potential for direct photolysis in a sunlit environment (EPA 1979). Irradiation experiments using a benzene solution of *N*-nitrosodiphenylamine have shown that *N*-nitrosodiphenylamine is photodecomposed at sunlight wavelengths (Sharma et al. 1986). The rate at which photolysis occurs was not determined. *N*-Nitrosodiphenylamine also reacts with hydroxyl radicals in the atmosphere. An estimated half-life for this reaction is 7 hours (HSDB 1990).

Water. The major environmental fate process for *N*-nitrosodiphenylamine in water is biodegradation. A static-culture flask-screening biodegradability test was performed using domestic waste water as the microbial inoculum and 5 and 10 ppm of *N*-nitrosodiphenylamine as the test compound (Tabak et al. 1981). At the end of 7 days, 87% degradation was achieved in the original culture dosed with 5 ppm, and 47% degradation was achieved in the original culture dosed with 10 ppm. After the second 7-day incubation period, 100% degradation was achieved in the first subculture dosed with 5 ppm, while 63% degradation was achieved in the first subculture dosed with 10 ppm. After the fourth 7-day incubation period, 98% degradation was achieved by the third subculture dosed with 20 ppm. These results showed that *N*-nitrosodiphenylamine was degradable, with rapid microbial adaptation at concentrations of 5 ppm and with more gradual microbial adaptation at concentrations of 10 ppm (Tabak et al. 1981). No studies were located regarding hydrolysis and oxidation of *N*-nitrosodiphenylamine.

Sediment and Soil. Biodegradation is the major environmental fate process for *N*-nitrosodiphenylamine in soil. In laboratory tests using a sandy loam soil, 68% of added *N*-nitrosodiphenylamine was degraded after 30 days of incubation, but amending the soil with wheat straw (to increase microbial activity) resulted in complete disappearance of added *N*-nitrosodiphenylamine in 10 days (Mallik and Tesfai 1981).

5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to *N*-nitrosodiphenylamine depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of *N*-nitrosodiphenylamine in unpolluted atmospheres and in pristine surface waters are often so low as to be near the limits of current analytical methods. In reviewing data on *N*-nitrosodiphenylamine levels monitored or estimated in the environment, it should also be noted that the amount of chemical identified analytically is not necessarily equivalent to the amount that is bioavailable.

Table 5-3 shows the lowest limit of detections that are achieved by analytical analysis in environmental and biological media.

Table 5-3. Lowest Limit of Detection Based on Standards[a]

Media	Detection limit	Reference
Air	NR	Fajen et al. 1979, 1980; NIOSH 1983
Water	NR	Rhoades et al. 1980
Soil	NR	NIOSH 1983
Blood and serum	0.01 ppm[b]	Pylpiw and Harrington 1981
Urine	0.1 ppm[b]	Pylpiw and Harrington 1981

[a] Detection limits based on using appropriate preparation and analytics. These limits may not be possible in all situations.
[b] Actual data are for N-nitroso-N-methylaniline; authors indicate that N-nitrosodiphenylamine yielded comparable results

NR = not reported

Detections of *N*-nitrosodiphenylamine in air, water, and soil at NPL sites are summarized in Table 5-4.

Table 5-4. *N*-Nitrosodiphenylamine Levels in Water, Soil, and Air of National Priorities List (NPL) Sites

Medium	Median[a]	Geometric mean[a]	Geometric standard deviation[a]	Number of concentrations	NPL sites
Water (ppb)	22	32.5	7,370	37	21
Soil (ppb)	2,500	3,000	18,600	30	23
Air (ppbv)	No data	No data	No data	No data	No data

[a] Concentrations found in ATSDR site documents from 1981 to 2015 for 1,854 NPL sites (ATSDR 2017). Maximum concentrations were abstracted for types of environmental media for which exposure is likely. Pathways do not necessarily involve exposure or levels of concern.

5.5.1 Air

No data were located regarding the levels of *N*-nitrosodiphenylamine in air.

5.5.2 Water

No data were located regarding the levels of *N*-nitrosodiphenylamine in drinking water. Only one positive detection was found for ambient surface waters. *N*-Nitrosodiphenylamine was detected (no concentration reported) in the Cuyahoga River, which feeds Lake Erie (Great Lakes Water Quality Board 1983).

5.5.3 Sediment and Soil

N-Nitrosodiphenylamine was measured at a concentration of 47 mg/kg (47,000 ppb) in a soil sample collected in 1978 near a manufacturing facility (NIOSH 1983). It has also been detected (no concentration reported) in the soil-sediment-water complex of the Love Canal near Niagara Falls, New York (Hauser and Bromberg 1982).

5.5.4 Other Media

No reports of *N*-nitrosodiphenylamine detection in food or other environmental media were found in the available literature.

5.6 GENERAL POPULATION EXPOSURE

The general population does not appear to be exposed to any background levels of *N*-nitrosodiphenylamine. No data were located regarding levels of *N*-nitrosodiphenylamine in air, drinking water, or foods.

The National Occupational Exposure Survey (NOES), conducted by NIOSH from 1981 to 1983 estimated that 1,093 workers employed at 137 plants were potentially exposed to *N*-nitrosodiphenylamine in the United States (NOES 1990). The NOES database does not contain information on the frequency, concentration. or duration of exposure to *N*-nitrosodiphenylamine. The survey provides only estimates of workers potentially exposed to chemicals in the workplace.

N-Nitrosodiphenylamine was detected in the workplace air of an Ohio tire chemical factory in the spring of 1978. The concentrations of *N*-nitrosodiphenylamine ranged from 0 to 47 $\mu g/m^3$ (0–6 ppb) (Fajen et al. 1979, 1980). A scraping from a staircase in the factory contained 15,000 ppm of *N*-nitrosodiphenylamine. Additional monitoring conducted in Ohio during the spring of 1978 found no detectable levels of *N*-nitrosodiphenylamine in the workplace air of an industrial rubber products factory, an aircraft tire factory, a synthetic rubber and latex factory, or three tire plants (Fajen et al. 1979, 1980).

Levels of *N*-nitrosodiphenylamine ranging from not detectable to 12.35 $\mu g/m^3$ (1.5 ppb) in workplace air samples were found at a Kelly-Springfield tire plant in 1979 in the United States (NIOSH 1984). Levels ranging from below detectable limits (5 ng per sample) to 160 ng/m^3 (0.02 ppb) were found in the breathing zone of curing press operators at a Uniroyal plant in Mishawaka, Indiana (NIOSH 1982).

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers involved in the production and use of *N*-nitrosodiphenylamine may constitute a group at risk because of the potential for occupational exposure. Persons living near a production facility or a hazardous waste site containing *N*-nitrosodiphenylamine may have a higher risk of exposure to *N*-nitrosodiphenylamine resulting from contact with contaminated air, drinking water, or soil. If microorganisms are found to nitrosate diphenylamine *in situ*, then workers exposed to this chemical may be at higher risk of *N*-nitrosodiphenylamine exposure. Persons living near facilities producing, or waste sites containing, diphenylamine might also be at increased risk of exposure to *N*-nitrosodiphenylamine via microbial production of the chemical.