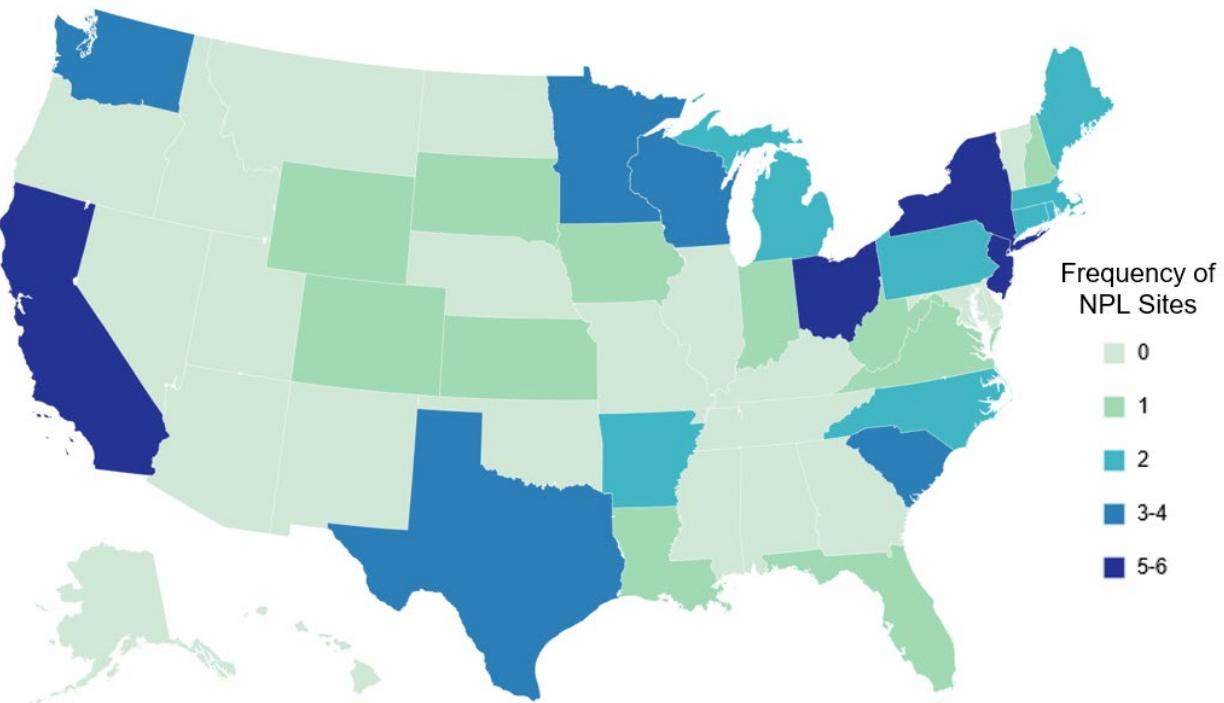


## CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

### 5.1 OVERVIEW

*n*-Hexane has been identified in at least 67 of the 1,868 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2022a). However, the number of sites in which *n*-hexane has been evaluated is not known. The number of sites in each state is shown in Figure 5-1.

**Figure 5-1. Number of NPL Sites with *n*-Hexane Contamination**



Source: ATSDR 2022a

- *n*-Hexane is both an anthropogenic and naturally occurring chemical. Anthropogenic hexane originates from refining crude oil and naturally occurring hexane is produced by plants, forest fires, and volcanoes.
- Vapors and emissions from refined petroleum products are the primary sources of *n*-hexane exposure to the general population.
- Since *n*-hexane has a very high vapor pressure and Henry's law volatility constant, it is expected to exist primarily in the vapor phase. In the atmosphere, the main degradation pathway will be through the reaction of free radicals such as hydroxyl radicals.

## 5. POTENTIAL FOR HUMAN EXPOSURE

- If *n*-hexane is introduced into deeper sediments or groundwater, hexane may be persistent due to limited biodegradation under anoxic conditions.

*n*-Hexane is a highly volatile component of the paraffin (also the alkane or aliphatic) fraction of crude oil and natural gas, and it is a constituent of heating and motor fuels refined from petroleum. Exposure from contact with vapors or emissions from these refined petroleum products is the most widespread form of low-level exposure for the general population. Most *n*-hexane in these fuels is oxidized as part of the combustion process to provide heat or drive internal combustion engines. Small amounts of *n*-hexane, along with other petroleum compounds, volatilize to the atmosphere during handling, storage in fuel tanks, or through incomplete combustion. Research suggests that certain fungi may be able to produce *n*-hexane (Ahearn et al. 1996). These fungi may be common in older buildings and in some parts of the country, and they may provide exposures from previously unsuspected indoor sources. *n*-Hexane is also produced as a relatively pure product for a number of specialized end uses, primarily as a solvent especially in glues and adhesives. Especially in urban areas, *n*-hexane may be a typical component of nonpoint source runoff when rainfall washes hydrocarbons deposited on roads and other surfaces into surface waters. Spills of refined petroleum products or of commercial *n*-hexane products may introduce *n*-hexane into soils or surface waters. Around urbanized areas, spill sites, refineries, tank storage facilities, underground storage tanks (e.g., at gas stations), or waste sites, can be sources of *n*-hexane subsequently transported into sediments or groundwater.

Once introduced into deeper sediments or groundwater, *n*-hexane may be persistent since its degradation by chemical hydrolysis is negligible and opportunities for biodegradation may be limited under anoxic conditions or where nutrients such as nitrogen or phosphorus are in limited supply. In the atmosphere, the main degradation pathways involve destruction through the action of free radicals such as hydroxyl radicals.

## 5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

### 5.2.1 Production

Normal hexane (*n*-hexane) is both an anthropogenic and naturally occurring chemical. *n*-Hexane is a minor constituent of crude oil and natural gas. Its inclusion in a variety of petroleum products is a consequence of refining operations that separate hydrocarbons within specific ranges of boiling points for such uses as heating oils or automotive fuels. Virtually all *n*-hexane is obtained from petroleum mixtures

## 5. POTENTIAL FOR HUMAN EXPOSURE

through controlled fractional distillation and other refinery-based processes (Speight 2006). *n*-Hexane may also be a metabolic byproduct from certain types of fungi (Ahearn et al. 1996).

Table 5-1 summarizes information on companies that reported the production, import, or use of *n*-hexane for the Toxics Release Inventory (TRI) in 2023 (TRI23 2024). TRI data should be used with caution since only certain types of industrial facilities are required to report. This is not an exhaustive list.

**Table 5-1. Facilities that Produce, Process, or Use *n*-Hexane**

State <sup>a</sup>	Number of facilities	Minimum amount on site in pounds <sup>b</sup>	Maximum amount on site in pounds <sup>b</sup>	Activities and uses <sup>c</sup>
AK	22	1,000 (or N/A)	49,999,999 (or N/A)	1, 3, 4, 5, 7, 8, 9, 12, 14
AL	20	0 (or N/A)	9,999,999 (or N/A)	1, 2, 3, 4, 5, 7, 8, 9, 10, 12, 13, 14
AR	10	0	9,999,999	1, 2, 3, 5, 6, 9, 10, 12, 14
AZ	15	100 (or N/A)	9,999,999 (or N/A)	1, 5, 9, 12
CA	65	0 (or N/A)	99,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 13, 14
CO	35	100 (or N/A)	499,999,999 (or N/A)	1, 2, 5, 6, 7, 8, 9, 10, 12, 13, 14
CT	6	1,000	9,999,999	2, 4, 7, 9, 10, 12
DE	2	10,000	999,999	1, 2, 3, 9, 10, 11
FL	31	1,000 (or N/A)	49,999,999 (or N/A)	1, 5, 9, 10, 11, 12, 13, 14
GA	16	100	9,999,999	1, 5, 6, 7, 8, 9, 10, 12
GU	5	0	999,999	1, 5, 7, 9, 12
HI	8	0	9,999,999	1, 2, 3, 4, 5, 6, 9, 12, 13, 14
IA	58	0	9,999,999	1, 2, 5, 6, 7, 8, 9, 10, 12, 13, 14
ID	4	1,000 (or N/A)	999,999 (or N/A)	1, 5, 9, 14
IL	50	0 (or N/A)	99,999,999 (or N/A)	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14
IN	50	0 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	32	0 (or N/A)	499,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KY	21	1,000 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
LA	78	0 (or N/A)	10,000,000,000 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MA	15	1,000 (or N/A)	9,999,999 (or N/A)	2, 4, 7, 8, 9, 10, 11, 12
MD	7	1,000 (or N/A)	9,999,999 (or N/A)	9, 10, 12
ME	7	1,000 (or N/A)	9,999,999 (or N/A)	1, 2, 3, 4, 5, 7, 9, 12
MI	42	0 (or N/A)	499,999,999 (or N/A)	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MN	30	1,000 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	26	0 (or N/A)	9,999,999 (or N/A)	1, 5, 7, 8, 9, 10, 11, 12, 13, 14
MP	2	100,000	9,999,999	1, 2, 3, 5, 7, 9
MS	15	1,000 (or N/A)	99,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 13, 14
MT	9	10,000 (or N/A)	499,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 8, 9, 12, 13, 14
NC	28	0 (or N/A)	9,999,999 (or N/A)	1, 5, 7, 9, 10, 11, 12

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-1. Facilities that Produce, Process, or Use n-Hexane**

State <sup>a</sup>	Number of facilities	Minimum amount on site in pounds <sup>b</sup>	Maximum amount on site in pounds <sup>b</sup>	Activities and uses <sup>c</sup>
ND	36	100 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
NE	27	100	9,999,999	1, 2, 3, 5, 7, 8, 9, 10, 12, 13, 14
NH	6	1,000 (or N/A)	9,999,999 (or N/A)	7, 9, 12
NJ	20	0 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 9, 12, 14
NM	28	0 (or N/A)	499,999,999 (or N/A)	1, 3, 5, 6, 8, 9, 11, 12, 13, 14
NV	10	0 (or N/A)	9,999,999 (or N/A)	1, 5, 7, 8, 9, 12
NY	20	0 (or N/A)	9,999,999 (or N/A)	1, 2, 4, 5, 7, 8, 9, 10, 12
OH	64	0 (or N/A)	499,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	48	0 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14
OR	5	10,000	9,999,999	1, 5, 7, 9, 12, 14
PA	35	0 (or N/A)	49,999,999 (or N/A)	1, 2, 5, 6, 7, 8, 9, 10, 12, 13, 14
PR	11	0 (or N/A)	49,999,999 (or N/A)	2, 3, 4, 5, 7, 8, 9, 12, 13, 14
RI	4	10,000 (or N/A)	9,999,999 (or N/A)	1, 5, 7, 9, 12
SC	9	100 (or N/A)	999,999 (or N/A)	1, 5, 7, 10, 12, 13, 14
SD	18	1,000	999,999	1, 2, 5, 7, 8, 9, 10, 12, 13, 14
TN	20	1,000 (or N/A)	9,999,999 (or N/A)	1, 3, 5, 7, 8, 9, 10, 11, 12, 13
TX	329	0 (or N/A)	999,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	19	10,000 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 14
VA	23	0 (or N/A)	999,999 (or N/A)	1, 5, 7, 9, 10, 12
VI	5	10,000 (or N/A)	49,999,999 (or N/A)	1, 5, 7, 9, 12, 14
WA	15	1,000 (or N/A)	49,999,999 (or N/A)	1, 2, 3, 5, 6, 7, 9, 12, 13, 14
WI	23	0 (or N/A)	9,999,999 (or N/A)	1, 2, 5, 7, 8, 9, 10, 11, 12, 13, 14
WV	17	1,000 (or N/A)	499,999,999 (or N/A)	1, 3, 5, 6, 7, 8, 9, 11, 12, 13, 14
WY	22	0 (or N/A)	9,999,999 (or N/A)	1, 2, 3, 4, 5, 6, 8, 9, 12, 13, 14

<sup>a</sup>Post office state abbreviations used.<sup>b</sup>Amounts on site reported by facilities in each state. Facilities may report N/A (not applicable) instead of a numeric value "if the waste stream that contains or contained the EPCRA Section 313 chemical is not directed to the relevant environmental medium, or if leaks, spills, and fugitive emissions cannot occur." (EPA 2022).<sup>c</sup>Activities/uses:

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

Note: Facilities that report N/A for amounts on site do not report activities/uses.

EPCRA = Emergency Planning and Community Right-to-Know Act

Source: TRI23 2024 (Data are from 2023)

## 5. POTENTIAL FOR HUMAN EXPOSURE

### 5.2.2 Import/Export

No current information concerning the import or export of *n*-hexane in the United States was located in the literature.

### 5.2.3 Use

A number of *n*-hexane uses have been identified. Its primary use is as an edible oil extractant for seed crops. Other uses include special-purpose solvent and cleaning agent and as a component of adhesives. Pure *n*-hexane is also used as a laboratory extractant and for instrument calibration.

*n*-Hexane is used mainly as an edible-oil extractant for a variety of seed crops such as soybeans, cottonseed, rape seed (canola), flax (linseed), mustard seed, peanuts, safflower seed, and corn germ, which are then processed into foods for humans or livestock (Bhagya and Srinivas 1992; Cravotto et al. 2022; Conkerton et al. 1995; Domínguez et al. 1995; Kim and Yoon 1990; Lawson 1995; Srinivas et al. 1992; Wanasundara and Shahidi 1994). While other petroleum-derived solvents (e.g., pentane) or other organic solvents (e.g., chloroform, methanol, ethanol, or ammonia-alcohol mixtures) are currently being studied or are used for certain processes, *n*-hexane has been widely used since the early part of this century, especially with soybeans, cottonseed, and linseed (Conkerton et al. 1995). *n*-Hexane is also used in the defatting and extraction of plant protein (Cravotto et al. 2022). Part of *n*-hexane's appeal relates to aesthetic properties such as preserving the colors of the original plant materials. Different extractant mixtures can also have significant effects on the levels of materials that can cause bitter tastes (e.g., tannins) and on the degree to which certain flatulence-causing sugars are removed. While other solvents could be used in the initial oil extraction phases, several decades of experience in combining the oil-extraction steps with other procedures to preserve desirable colors and eliminate unwanted tastes or other undesirable food properties have worked to maintain a heavy reliance on *n*-hexane for edible-oil extraction (Lawson 1995). After extraction, the *n*-hexane is distilled off and trace amounts may remain in the final extracted oil.

*n*-Hexane has other major uses as a special-purpose solvent and cleaning agent (degreaser) in such industries as textile manufacture, shoe and leather making, and furniture manufacturing (Jørgensen and Cohr 1981). It is used in the printing industry as a cleaner and as a component of some inks (EPA 1996; Wadden et al. 1995). Facilities that use rotogravure printers (facilities that produce catalogues, magazines, “glossy” newspaper inserts, or telephone directories) or similar rotogravure or flexographic

## 5. POTENTIAL FOR HUMAN EXPOSURE

technologies (for labels, gift wrap, metal foils, flexible packaging materials, and some floor coverings) also use *n*-hexane (EPA 1996).

While not used in most glues or epoxy cements (Rastogi 1993), *n*-hexane is the solvent used in “rubber” cement (also known as gum adhesive) widely used in schools and libraries and by artists (McCann 1992). Various glues, adhesives, and leather-dressing preparations, especially those used in assembling shoes, may contain *n*-hexane (Cardona et al. 1993; Periago et al. 1993; Takeuchi et al. 1993). In bookbinding and leather working, *n*-hexane, often mixed with other hydrocarbon solvents, is used as a carrier for cedar oil, beeswax, or lanolin dressings (Jørgensen and Cohn 1981; Roberts and Etherington 1996).

Adhesives, cleaners, or lacquers containing *n*-hexane are also used to prepare the veneers used in making many types of furniture or ornamental boxes (Graham et al. 1995). Additional uses for adhesives containing *n*-hexane include holding the ends of tin cans during the sealing process (Bachmann et al. 1993) and holding strings or yarns together to create the cores of balls used in several sports (Huang et al. 1991). Certain types of tapes, bandages, and dressings used in hospitals also use adhesives containing *n*-hexane (Jørgensen and Cohn 1981).

In the petrochemical industry, lighter alkane fractions, including *n*-hexane, may be used as feedstocks in the manufacture of polyethylene or polypropylene (Jørgensen and Cohn 1981). In the manufacture of truck and automobile tires, *n*-hexane is a solvent in mixtures (called “thinners”) used to adjust the viscosity of the rubber while it is being polymerized and formed into tires (Jørgensen and Cohn 1981; Van Ert et al. 1980).

Furthermore, *n*-hexane may be used as a carrier or aerosol (propellant) agent in some perfumes (Bouhamra 1995; Jørgensen and Cohn 1981). It is used in the pharmaceutical industry to help shape pills and tablets, which are then dried to vent off the *n*-hexane before packaging (Jørgensen and Cohn 1981). *n*-Hexane is also used in some typeover correction (“white-out”) fluids (Ong et al. 1993). It has been used in many types of non-mercury thermometers, especially for thermometers used in low temperature ranges (EPA 2000). New roofing materials using rubber or plastic films and membranes held together by adhesives, sealants, or hardening agents may contain *n*-hexane (Herbert et al. 1995).

Pure *n*-hexane is widely used in laboratories as an extractant for nonpolar compounds and in calibrating instruments for analyses of VOCs or total petroleum hydrocarbons (TPH) (Kanatharana et al. 1993). Since such analyses may require very high levels of purity, laboratories sometimes carry out their own

## 5. POTENTIAL FOR HUMAN EXPOSURE

fractional distillation or other pretreatment-purification procedures to remove petroleum hydrocarbon impurities found in commercially available grades of *n*-hexane (Kanatharana et al. 1993).

Finally, *n*-hexane may be a component of many types of commercial preparations or in mixtures produced in small batches onsite such as paint thinners, general-purpose solvents, degreasing agents, or cleaners. For instance, until the 1970s, naphtha, a mixture with a high *n*-hexane content, was widely used as a dry-cleaning agent. Since the early 1900s, construction workers, metal workers, janitors, furniture workers, motor-vehicle mechanics, and print-shop workers have used these general-purpose mixtures. Such mixtures have also been used extensively for home repair and hobby projects. These mixtures have wide variations in their compositions but often contain up to 20% *n*-hexane even when the main components are other petroleum alkane fractions (e.g., kerosene), aromatic hydrocarbons (e.g., toluene), chlorinated hydrocarbon solvents, or other organic liquids (Farmer 1996; Veulemans et al. 1987).

### 5.2.4 Disposal

Limited information was located in the literature concerning the disposal of *n*-hexane. Since it is highly flammable, *n*-hexane, or mixtures with significant amounts of *n*-hexane, are regulated under the Resource Conservation and Recovery Act (RCRA) disposal procedures covering D001 wastes for ignitable wastes and petroleum solvents. For printing operations, it could also be considered under the K086 ink sludges designation (EPA 1996). *n*-Hexane is listed as a toxic substance under Section 313 of the Emergency Planning and Community Right to Know Act (EPCRA) under Title III of the Superfund Amendments and Reauthorization Act (SARA) (EPA 1993). It is also listed as a Hazardous Air Pollutant (HAP) in the Clean Air Act Amendments of 1990 (EPA 2000). Disposal of wastes containing *n*-hexane is controlled by a number of federal regulations.

## 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 2022b). This is not an exhaustive list. Manufacturing and processing facilities are required to report information to the TRI only if they employ  $\geq 10$  full-time employees; if their facility's North American Industry Classification System (NAICS) codes is covered under EPCRA Section 313 or is a federal facility; and if their facility manufactures (defined to include importing) or processes any TRI chemical in excess of 25,000 pounds, or otherwise uses any TRI chemical in excess of 10,000 pounds, in a calendar year (EPA 2022b).

## 5. POTENTIAL FOR HUMAN EXPOSURE

Since *n*-hexane is a component of refined petroleum products, there is considerable potential for releases to environmental media through the use of heating and motor fuels. Table 5-2 summarizes the uses of petroleum products according to major demand categories (e.g., "transportation") and displays estimated use levels in barrels (and liter equivalents) and by percentages for the various end-use demands for specific fuel types (e.g., kerosene or fuel oil). While *n*-hexane can be a minor constituent (<1% by weight) of several of these petroleum products, its physical properties as a light alkane make it most suitable for use in gasoline. Approximately 98% of the demand for gasoline involves transportation, mainly cars and trucks. The composition of gasolines has changed over the years, mainly in an effort to maintain the so-called octane ratings of the fuels. Since the 1980s, the growing use of nonleaded gasolines has led to a growing percentage of high-octane benzene and toluene in gasoline blends. For modern gasoline mixtures, the total percentage by weight of the *n*-hexane component is approximately 3% (Brugnone et al. 1991; Heath et al. 1993; Stelljes and Watkin 1993). Of the 2,608 million barrels of motor gasoline consumed for transportation in 1992 (designated "transportation" in Table 5-2), about 27,300 million pounds (12,409 million kg) are from the *n*-hexane fraction (PennWell 1994; Stevens 1988). This figure is about 76 times the 358 million pounds (143 million kg) of commercial *n*-hexane produced annually in the 1970s (Marks et al. 1980). Most gasoline, along with its *n*-hexane fraction, is consumed during its combustion in motor cars and other engines. However, gasoline use results in a variety of emission losses from refueling, evaporation while gasoline is stored in fuel tanks or ignition systems, and exhaust releases when there is incomplete combustion of fuels (EPA 1994a). EPA only tracks trends in total hydrocarbon or total VOC emissions, so that quantitative estimates for the *n*-hexane released from automobiles and trucks are not available. Assuming that only 1% of the *n*-hexane of motor fuels is released to environmental media, such releases could be on the same order of magnitude as the total amount of relatively pure *n*-hexane associated with the major end-uses described in Section 5.2.3.

In addition to emissions to the atmosphere, releases from heating and motor fuel uses to other environmental media are possible. For example, soil and water may contain *n*-hexane as a result of leaks and spills at refineries, pipelines, large tank batteries (or tank "farms"), above- and below-ground storage tanks, tanker trucks, and railroad tanker cars. Additionally, minor environmental releases could occur at garages or around homes and workplaces. Crude oil spills also result in the release of *n*-hexane to the air or other environmental media.

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-2. Demand Patterns for Major Petroleum Products (1992)<sup>a</sup>**

Product	Residential	Commercial	Industrial	Transportation	Electric utilities	Total
Motor gasoline <sup>b</sup>	0 (0.0) 0	15 (<1.0) 2,385	37 (1.4) 5,883	2,608 (98.0) 414,672	0 (0.0) 0	2,660
Kerosene	11 (73.3) 1,749	2 (13.3) 318	2 (13.3) 318	0 (0.0) 0	0 (0.0) 0	15
Distillate fuel oil	148 (13.6) 23,532	80 (7.3) 12,720	196 (18.0) 31,164	654 (60.0) 103,986	12 (1.1) 1,908	1,090
Residual fuel oil	0 (0.0) 0	30 (7.5) 4,770	62 (15.5) 9,858	172 (42.9) 27,348	136 (33.9) 21,942	400
Liquid petroleum gas and ethanes	106 (16.5)	19 (3.0)	513 (79.9)	5 (0.8)	0 (0.0)	642

<sup>a</sup>Expressed in millions of barrels (percent of total sectoral demand; 1 barrel = 42 U.S. gallons = 159 L.

<sup>b</sup>Typically contains >1% *n*-hexane.

Source: PennWell 1994

In addition to releases associated with the ordinary use of refined petroleum products as a fuel, ongoing research (Ahearn et al. 1996) suggests that a variety of fungi found in ducts and insulation materials in homes or office buildings are capable of releasing gases that include *n*-hexane. There is also evidence that marine phytoplankton produce a variety of non-methane hydrocarbons, including small amounts of *n*-hexane, from the metabolism of polyunsaturated lipids in dissolved organic materials (McKay et al. 1996). Very small amounts of *n*-hexane may also be among the biogenic emissions from different types of terrestrial vegetation (Isidorov et al. 1985; Winer et al. 1992).

When buildings have poor ventilation properties, commonly referred to as “sick-building syndrome” (Sundell 1996), the indoor air releases of *n*-hexane may sometimes be sufficient to pose public health concerns. Lastly, *n*-hexane is also among the various off-gassing constituents encountered at sanitary landfills (Brosseau and Heitz 1994; O’Leary and Walsh 1995).

### 5.3.1 Air

Most releases of *n*-hexane to environmental media are to air; as an example, see Table 5-3. Based on its Henry’s law constant, *n*-hexane discharged to water will volatilize rapidly; however, the amount volatilized will vary depending on several factors including the temperature, turbulence, and depth of the receiving water. *n*-Hexane spilled onto surface soils will also volatilize to the air. In addition to releases from commercial applications as edible oil extraction, the other major sources of atmospheric releases would be from emissions related to the *n*-hexane contained in heating and motor fuels.

## 5. POTENTIAL FOR HUMAN EXPOSURE

Estimated releases of 41,937,771 pounds (~19,022 metric tons) of *n*-hexane to the atmosphere from 1,497 domestic manufacturing and processing facilities in 2023, accounted for about 91% of the estimated total environmental releases from facilities required to report to the TRI (TRI23 2024). These releases are summarized in Table 5-3.

**Table 5-3. Releases to the Environment from Facilities that Produce, Process, or Use *n*-Hexane<sup>a</sup>**

State <sup>c</sup>	RF <sup>d</sup>	Reported amounts released in pounds per year <sup>b</sup>								On- and off-site
		Total release								
		Air <sup>e</sup>	Water <sup>f</sup>	UI <sup>g</sup>	Land <sup>h</sup>	Other <sup>i</sup>	On-site <sup>j</sup>	Off-site <sup>k</sup>		
AL	20	1,304,424	384	0 <sup>l</sup>	1,948	30	1,306,365	422	1,306,787	
AK	22	24,007	0	0	19	259	24,026	259	24,285	
AZ	15	4,549	0	0	5	701	4,554	701	5,255	
AR	10	789,343	80	0	18	0	789,348	93	789,441	
CA	59	134,031	217	0	363	1,203	134,066	1,748	135,814	
CO	35	85,060	0	48,062	125	238	85,096	48,390	133,486	
CT	6	2,786	4	0	8	0	2,798	0	2,798	
DE	2	11,911	5	0	0	0	11,916	0	11,916	
FL	31	78,985	0	901	59	6,087	79,887	6,145	86,032	
GA	16	1,306,902	10,164	0	1	0	1,306,903	10,164	1,317,066	
HI	8	60,480	0	0	5	1	60,480	6	60,486	
ID	4	1,329	0	0	1	0	1,329	1	1,330	
IL	46	5,075,625	6,586	0	30	2,789	5,076,436	8,594	5,085,030	
IN	49	3,274,350	1,467	0	1,724	4,258	3,275,344	6,455	3,281,800	
IA	58	5,432,874	32,439	0	0	250	5,432,874	32,689	5,465,563	
KS	32	893,493	205	14,016	1,576	44	893,600	15,734	909,334	
KY	21	496,583	130	0	180	7	496,840	60	496,901	
LA	73	2,919,289	1,661	14,972	5,959	4	2,935,338	6,547	2,941,885	
ME	7	2,439	28	0	734	4	2,440	765	3,205	
MD	7	246,566	65	0	6	0	246,637	0	246,637	
MA	15	33,422	1	0	0	46,368	33,422	46,368	79,791	
MI	41	391,225	30	0	1	684	391,226	714	391,940	
MN	30	2,794,703	1,054	0	0	5	2,794,707	1,055	2,795,762	
MS	15	174,061	13	0	0	1,438	174,074	1,438	175,512	
MO	26	2,049,662	267	0	0	34,122	2,049,662	34,389	2,084,051	
MT	9	82,779	5	500	142	0	82,924	502	83,426	

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-3. Releases to the Environment from Facilities that Produce, Process, or Use n-Hexane<sup>a</sup>**

State <sup>c</sup>	RF <sup>d</sup>	Reported amounts released in pounds per year <sup>b</sup>							On- and off-site	
		Total release								
		Air <sup>e</sup>	Water <sup>f</sup>	UI <sup>g</sup>	Land <sup>h</sup>	Other <sup>i</sup>	On-site <sup>j</sup>	Off-site <sup>k</sup>		
NE	26	2,423,669	480	0	380	0	2,423,669	860	2,424,529	
NV	10	3,555	0	0	0	18	3,555	18	3,572	
NH	6	227	3	0	0	0	230	0	230	
NJ	20	34,751	36	0	0	1,357	34,787	1,357	36,144	
NM	28	123,606	0	599,514	221,479	40,000	654,921	329,679	984,600	
NY	20	18,337	1	0	3	66	18,338	69	18,407	
NC	27	1,202,825	2,688	0	1	27,195	1,202,847	29,862	1,232,709	
ND	35	1,112,664	2,067	88,997	3,356	0	1,112,665	94,419	1,207,084	
OH	63	1,862,962	7,116	9,993	369	3,253	1,863,228	20,465	1,883,693	
OK	47	370,286	10	171,125	8,657	0	386,130	163,948	550,077	
OR	5	2,732	13	0	168	53	2,771	195	2,966	
PA	35	298,086	490	6,071	16	20,797	298,291	27,169	325,460	
RI	4	2,028	5	0	1	0	2,033	1	2,034	
SC	9	249,894	15	0	95	0	249,982	22	250,004	
SD	18	1,639,024	642	0	0	0	1,639,024	642	1,639,667	
TN	20	339,292	359	0	11	1,561	339,292	1,930	341,222	
TX	327	3,685,185	1,676	1,552,322	205,062	134,771	3,880,297	1,698,719	5,579,016	
UT	18	110,984	21	12,821	56	58	110,993	12,947	123,940	
VA	22	419,107	38	0	0	280	419,107	318	419,425	
WA	15	58,556	121	0	90	0	58,678	89	58,767	
WV	17	47,642	0	0	142	0	47,677	107	47,784	
WI	23	86,710	0	0	3	0	86,710	3	86,713	
WY	22	87,120	0	666,000	10,240	0	87,724	675,635	763,360	
GU	5	2,377	0	0	0	0	2,377	0	2,377	
MP	2	845	0	0	0	0	845	0	845	
PR	11	15,491	0	0	0	0	15,491	0	15,491	

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-3. Releases to the Environment from Facilities that Produce, Process, or Use n-Hexane<sup>a</sup>**

State <sup>c</sup>	RF <sup>d</sup>	Reported amounts released in pounds per year <sup>b</sup>							On- and off-site	
		Total release								
		Air <sup>e</sup>	Water <sup>f</sup>	UI <sup>g</sup>	Land <sup>h</sup>	Other <sup>i</sup>	On-site <sup>j</sup>	Off-site <sup>k</sup>		
VI	5	68,937	143	0	0	23	69,080	23	69,103	
Total	1,497	41,937,771	70,729	3,185,295	463,033	327,921	42,703,035	3,281,714	45,984,749	

<sup>a</sup>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.

<sup>b</sup>Data in TRI are maximum amounts released by each facility.

<sup>c</sup>Post office state abbreviations are used.

<sup>d</sup>Number of reporting facilities.

<sup>e</sup>The sum of fugitive and point source releases are included in releases to air by a given facility.

<sup>f</sup>Surface water discharges, wastewater treatment (metals only), and publicly owned treatment works (POTWs) (metal and metal compounds).

<sup>g</sup>Class I wells, Class II-V wells, and underground injection.

<sup>h</sup>Resource Conservation and Recovery Act (RCRA) subtitle C landfills; other onsite landfills, land treatment, surface impoundments, other land disposal, other landfills.

<sup>i</sup>Storage only, solidification/stabilization (metals only), other off-site management, transfers to waste broker for disposal, unknown.

<sup>j</sup>The sum of all releases of the chemical to air, land, water, and underground injection wells.

<sup>k</sup>Total amount of chemical transferred off-site, including to POTWs.

<sup>l</sup>Due to reporting guidelines, a zero may represent that the facility or facilities in each state's row reported "0" and "NA" or left the cell blank in their Form R submission.

RF = reporting facilities; RQ = reportable quantity; UI = underground injection

Source: TRI23 2024 (Data are from 2023)

EPA's National Emission Inventory (NEI) database contains information regarding sources that emit criteria air pollutants (CAPs) and their precursors, and hazardous air pollutants (HAPs) for the 50 United States, Washington DC, Puerto Rico, and the U.S. Virgin Islands. Emissions are estimated from multiple sources, including state and local environmental agencies; the TRI database; computer models for on- and off-road emissions; and databases related to EPA's Maximum Achievable Control Technology (MACT) programs to reduce emissions of HAPs. Hexane emissions estimated from the 2017 inventory are summarized in Table 5-4.

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-4. Estimated Hexane Emitted in Pounds to the Environment According to EPA's National Emission Inventory**

Emission sector	Pounds of hexane emitted
Mobile; on-road gasoline light duty vehicles	72,224,392
Mobile; non-road equipment; gasoline	29,212,385
Industrial processes; not elsewhere classified	25,263,505
Gas stations	16,912,830
Solvent; industrial surface coating and solvent use	11,771,007
Fires; wildfires	8,423,741
Industrial processes; oil and gas production	7,122,755
Industrial processes; chemical manufacturing	6,875,081
Miscellaneous non-industrial; not elsewhere classified	6,754,985
Industrial processes; storage and transfer	6,749,765
Bulk gasoline terminals	4,377,265
Fuel combustion; industrial boilers, internal combustion engines; natural gas	3,290,331
Fires; prescribed fires	3,154,563
Industrial processes; petroleum refineries	1,513,562
Mobile; on-road gasoline heavy duty vehicles	1,495,321
Fuel combustion; electric generation; natural gas	1,189,607
Solvent; non-industrial surface coating	1,045,477
Agriculture; livestock waste	913,252
Fuel combustion; residential; natural gas	822,820
Fuel combustion; commercial/institutional; natural gas	808,868
Fires; agricultural field burning	796,004
Solvent; degreasing	589,792
Mobile; on-road diesel heavy duty vehicles	539,283
Waste disposal	311,943
Fuel combustion; industrial boilers, internal combustion engines; coal	256,527
Mobile; commercial marine vessels	241,278
Mobile; non-road equipment; diesel	198,891
Solvent; consumer and commercial solvent use	196,243
Mobile; on-road diesel light duty vehicles	171,854
Mobile; locomotives	171,448
Fuel combustion; industrial boilers, internal combustion engines; other	160,511
Industrial processes; ferrous metals	103,250
Industrial processes; pulp and paper	96,948
Industrial processes; non-ferrous metals	80,220
Fuel combustion; industrial boilers, internal combustion engines; biomass	67,690
Fuel combustion; electric generation; oil	67,417
Mobile; aircraft	38,759

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-4. Estimated Hexane Emitted in Pounds to the Environment According to EPA's National Emission Inventory**

Emission sector	Pounds of hexane emitted
Solvent; graphic arts	38,418
Industrial processes; cement manufacture	32,879
Commercial cooking	29,751
Fuel combustion; industrial boilers, internal combustion engines; oil	28,157
Fuel combustion; electric generation; coal	21,712
Fuel combustion; electric generation; other	11,953
Industrial processes; mining	6,832
Fuel combustion; comm/institutional; other	3,884
Fuel combustion; comm/institutional; coal	2,697
Fuel combustion; comm/institutional; oil	2,388
Fuel combustion; comm/institutional; biomass	1,529
Fuel combustion; electric generation; biomass	749
Fuel combustion; residential; oil	499
Solvent; dry cleaning	47
Dust; construction dust	4
Total	112,754,292

Source: EPA 2022a

### 5.3.2 Water

Estimated releases of 70,729 pounds (~32.08 metric tons) of *n*-hexane to surface water from 1,497 domestic manufacturing and processing facilities in 2023, accounted for <1% of the estimated total environmental releases from facilities required to report to the TRI (TRI23 2024). This estimate includes releases to waste water treatment and publicly owned treatment works (POTWs) (TRI23 2024). These releases are summarized in Table 5-3.

*n*-Hexane is probably released to water from a number of sources including industrial discharges, effluents from municipal waste-treatment plants, and nonpoint-source runoff from roads and other surfaces. Insufficient information is available to quantify the releases from all sources in a comprehensive fashion.

## 5. POTENTIAL FOR HUMAN EXPOSURE

### 5.3.3 Soil

Estimated releases of 463,033 pounds (~210.03 metric tons) of *n*-hexane to soil from 1,497 domestic manufacturing and processing facilities in 2023, accounted for about 1% of the estimated total environmental releases from facilities required to report to the TRI (TRI23 2024). An additional 3,185,295 pounds (~1,444.83 metric tons), constituting about 7% of the total environmental emissions, were released via underground injection (TRI23 2024). These releases are summarized in Table 5-3.

*n*-Hexane is probably released to soil or sediments from spills and during the landfilling of sludges and other wastes generated from industrial processes and municipal sewage treatment; however, no specific quantitative information concerning levels for *n*-hexane released from wastes was identified in the literature.

## 5.4 ENVIRONMENTAL FATE

### 5.4.1 Transport and Partitioning

The physical properties of *n*-hexane (see Table 4-2) that affect its transport and partitioning in the environment are: water solubility of 9.5 mg/L; log K<sub>ow</sub> (octanol/water partition coefficient), estimated as 2.90 or 3.90; Henry's law constant, 1.003 or 1.3 atm·m<sup>3</sup> mol; and vapor pressure, 138 mmHg at 25°C. As with many alkanes, experimental methods for the estimation of the K<sub>oc</sub> parameter are lacking, so that estimates must be made based on theoretical considerations (Montgomery 1991).

**Air.** Organics with a vapor pressure of >10<sup>-4</sup> mmHg should exist almost entirely in the vapor phase in the atmosphere (Eisenreich et al. 1981). Hexane, which has a vapor pressure of 138 mmHg at 25°C, is not expected to partition from the vapor phase to particulates in the atmosphere.

**Water.** The dominant transport process from water is volatilization. Based on mathematical models developed by the EPA, the half-life for *n*-hexane in bodies of water with any degree of turbulent mixing (e.g., rivers) would be <3 hours. For standing bodies of water (e.g., small ponds), a half-life no longer than 1 week (6.8 days) is estimated using the Exposure Analysis Modeling System (EXAMS) (EPA 2004). Based on the log K<sub>ow</sub> and the estimated log K<sub>oc</sub> (see Table 4-2), *n*-hexane is not expected to become concentrated in biota (Swann et al. 1983). An estimated bioconcentration factor (BCF) of

## 5. POTENTIAL FOR HUMAN EXPOSURE

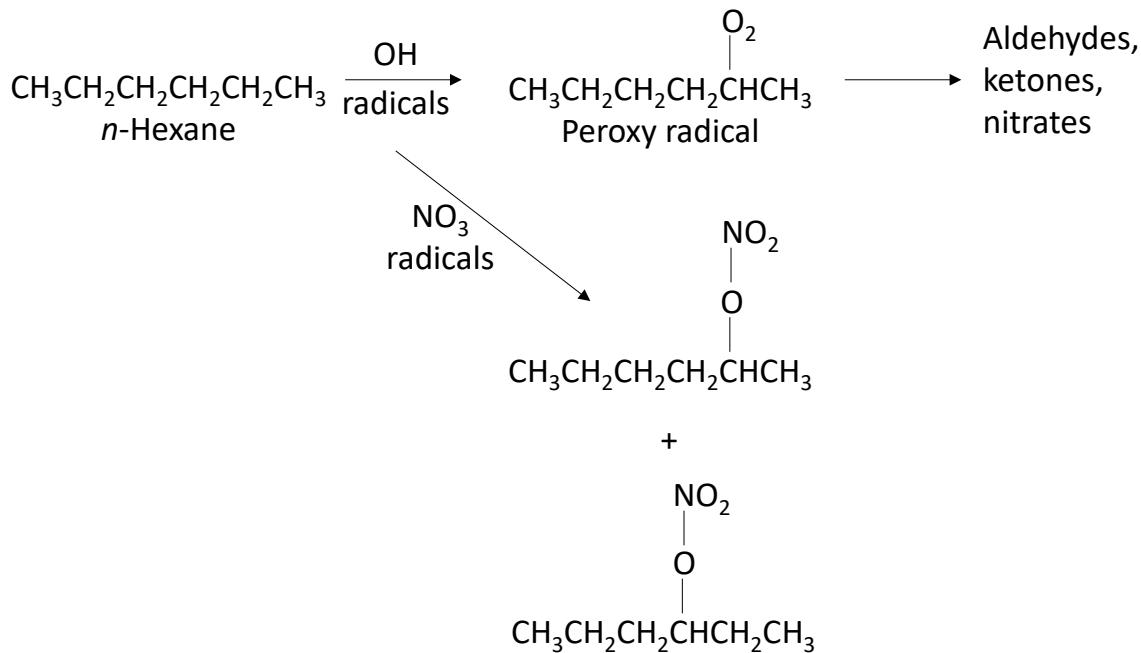
174 and an estimated bioaccumulation factor (BAF) of 307 suggests a low potential for *n*-hexane to bioconcentrate or bioaccumulate in trophic food chains (EPA 2012).

**Sediment and Soil.** In soil, the dominant transport mechanism for *n*-hexane present near the surface probably is volatilization (based on its Henry's law constant, water solubility, vapor pressure, and  $K_{oc}$ ), but no experimental information focusing directly on *n*-hexane was found to confirm this assumption. While its estimated  $K_{oc}$  values suggest a moderate ability to sorb to soil particles, *n*-hexane has a density (0.6606 g/mL at 20°C) well below that of water and a very low water solubility of 9.5 mg/L. *n*-Hexane would, therefore, be viewed as a light nonaqueous phase liquid (LNAPL), which would suggest a low potential for leaching into the lower soil depths since the *n*-hexane would tend to float on the top of the saturated zone of the water table (Feenstra et al. 1991; Hunt et al. 1988). Unless present in deeper soil layers (which can sometimes happen at waste sites or with underground storage tank leaks), *n*-hexane would generally stay near the soil surface and, if not appreciably sorbed into the soil matrix, would likely volatilize to the atmosphere. Exceptions would involve locations with shallow groundwater tables where there were large spills of hexane products. In such cases, the *n*-hexane could spread out to contaminate a large volume of soil materials.

### 5.4.2 Transformation and Degradation

**Air.** *n*-Hexane does not absorb ultraviolet (UV) light at 290 nm and is thus not expected to undergo direct photolysis reactions. The dominant tropospheric removal mechanism for *n*-hexane is generally regarded to be decomposition by hydroxyl radicals (Atkinson and Carter 1984; Atkinson et al. 1982). Calculations assuming typical hydroxyl radical concentrations suggest a half-life of approximately 1.96 days (EPA 2012). While *n*-hexane can react with nitrogen oxides to produce ozone precursors under controlled laboratory conditions (Montgomery 1991), the smog-producing potential of *n*-hexane is very low compared to that of other alkanes or chlorinated VOCs (Kopczynski et al. 1972). Hydroxyl ion reactions in the upper troposphere, therefore, are probably the primary mechanisms for *n*-hexane degradation in the atmosphere. As with most alkanes, *n*-hexane is resistant to hydrolysis (Lyman et al. 1982). The proposed decomposition of *n*-hexane in air is shown in Figure 5-2.

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Figure 5-2. Degradation of n-Hexane in Air by Free Radicals**

Source: Atkinson 1985

**Water.** Although few data are available dealing explicitly with the biodegradation of *n*-hexane in water, neither hydrolysis nor biodegradation in surface waters appears to be rapid compared with volatilization. In surface waters, as in the atmosphere, alkanes such as *n*-hexane would be resistant to hydrolysis (Lyman et al. 1982). Biodegradation is the most significant degradation mechanism in groundwater. One study was identified (McClay et al. 1995) that documented the ability of *Pseudomonas mendocina* bacteria to metabolize *n*-hexane in laboratory microcosms simulating groundwater conditions. Mixed bacterial cultures as well as pure cultures are documented as capable of metabolizing *n*-hexane under aerobic conditions (Heringa et al. 1961; Rosenberg et al. 1992). A study of a biofiltration system to remove VOCs from air used a sludge-like composting biofiltering system that was effective in causing the biodegradation of *n*-hexane (Morgenroth et al. 1996); this study involved a special composting system to allow the introduction of nitrogen fertilizers to overcome a nutrient limitation. Most of the available literature deals with petroleum mixtures containing several types of alkanes. In general, linear alkanes (such as *n*-hexane) are viewed as the most readily biodegradable fractions in petroleum (Leahy and Colwell 1990), particularly when oxygen is present in solution.

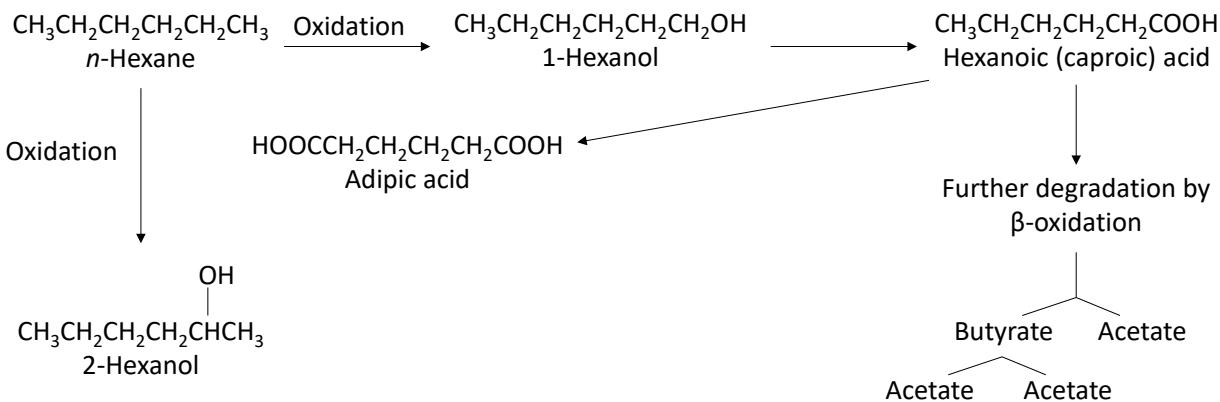
Since *n*-hexane is highly volatile, it is often excluded from the list of constituents included in studies on biodegradation or bioremediation of petroleum wastes or in studies of surface waters receiving pollutant loads from runoff or discharges. Attention is generally focused on complex mixtures of hydrocarbons,

## 5. POTENTIAL FOR HUMAN EXPOSURE

starting with fractions heavier or less volatile chain alkanes (usually C10 or longer), aromatics such as benzene or toluene, and polycyclic aromatic hydrocarbons (PAHs) than the lighter constituents of gasoline (Crawford et al. 1995; Latimer et al. 1990; Rosenberg et al. 1992; Sauer et al. 1993; Shaw et al. 1986). Once introduced into groundwater, *n*-hexane may be fairly persistent since its degradation by chemical hydrolysis is slow and opportunities for biodegradation may be limited under anoxic conditions or where nutrients such as nitrogen or phosphorus are in limited supply.

**Sediment and Soil.** The findings presented on bioremediation in groundwater are relevant for many soil and sediment systems. Figure 5-3 outlines the probable biodegradation of *n*-hexane based on metabolites isolated from a pure culture of *Pseudomonas* (Heringa et al. 1961). The most important biodegradation processes involve the conversion of the *n*-hexane to primary alcohols, aldehydes, and, ultimately, into fatty acids. Similar processes are encountered with other light hydrocarbons such as heptane. In general, unless the *n*-hexane is buried at some depth within a soil or sediment, volatilization is generally assumed to occur at a much more rapid rate than chemical or biochemical degradation processes. Once introduced into deeper sediments, *n*-hexane may be fairly persistent since its degradation by chemical hydrolysis is slow and opportunities for biodegradation may be limited under anoxic conditions or where nutrients such as nitrogen or phosphorus are in limited supply.

**Figure 5-3. Aerobic Biodegradation of *n*-Hexane in Sediment and Soil**



Source: Heringa et al. 1961

## 5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to *n*-hexane depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of

## 5. POTENTIAL FOR HUMAN EXPOSURE

*n*-hexane 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*-hexane 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.

The widespread use of *n*-hexane as an extractant in the laboratory creates problems in interpreting concentration readings at low levels. Even with good quality control, it may often be impossible to determine whether to attribute a measured value to the actual levels in a sample or to contamination from *n*-hexane in the laboratory environment (Otson et al. 1994). For the most part, *n*-hexane is not a common target analyte from water or soil samples. While data based on ambient air samples or sampling in the air of various workplace or residential environments are more numerous, most EPA regulatory programs rely on bulk measurements of total hydrocarbons or total volatile compounds rather than on measurements of specific compounds such as *n*-hexane (Bishop et al. 1994; DeLuchi 1993).

Table 5-5 shows the lowest limit of detections that are achieved by analytical analysis in environmental media. An overview summary of the range of concentrations detected in environmental media is presented in Table 5-6.

**Table 5-5. Lowest Limit of Detection Based on Standards<sup>a</sup>**

Media	Detection limit	Reference
Air (ppm)	0.093	OSHA 2010
Drinking water	0.05	Biziuk et al. 1996
Surface water and groundwater	0.05	Biziuk et al. 1996
Soil	0.5	Roberts and Burton 1994
Sediment	0.5	Roberts and Burton 1994
Whole blood (ng/mL)	0.122	CDC 2017

<sup>a</sup>Detection limits based on using appropriate preparation and analytics. These limits may not be possible in all situations.

**Table 5-6. Summary of Environmental Levels of *n*-Hexane**

Media	Low	High	For more information
Outdoor air (ppbv)	0.01	82	Section 5.5.1
Indoor air (ppbv)	0.01	2,500 (ppmv)	Section 5.5.1
Surface water (ppb)	1.5	7.8	Section 5.5.2

## 5. POTENTIAL FOR HUMAN EXPOSURE

The available data on the levels of *n*-hexane in air, water, or soil at NPL sites are listed in Table 5-7 (ATSDR 2022a).

**Table 5-7. *n*-Hexane Levels in Water, Soil, and Air of National Priorities List (NPL) Sites**

Medium	Median <sup>a</sup>	Geometric mean <sup>a</sup>	Geometric standard deviation <sup>a</sup>	Number of quantitative measurements	NPL sites
Water (ppb)	91	91	1	2	1
Soil (ppb)			No data		
Air (ppbv)	2.25	13.7	185	14	12

<sup>a</sup>Concentrations found in ATSDR site documents from 1981 to 2022 for 1,868 NPL sites (ATSDR 2022a). 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

*n*-Hexane is found at low levels in both rural and urban ambient air, with concentrations generally well below 55 ppbv for ambient air. In remote sites, readings of <0.5 ppbv are typical. A study of four rural sites in southern Canada showed median ambient air concentrations of *n*-hexane in the range of 0.01–0.12 ppbv (Bottenheim and Shepherd 1995). Higher levels can be encountered in urban areas, largely due to emissions from automobile exhaust. In the polluted atmosphere of the Los Angeles central business district, ambient air concentrations as high as 27 ppbv were documented in the 1960s (Neligan 1962); these levels are very similar to the concentrations of *n*-hexane measured in automobile exhaust collected during the same time period. Samples from Los Angeles in 1968 showed *n*-hexane levels of 82 ppbC (14 ppbv) (Kopczynski et al. 1972). With progressive improvements in emission controls, the levels of many air pollutants in urbanized areas today are generally far lower. A study of average VOC concentrations in the ambient air of several large cities showed the following results for *n*-hexane: Vienna 2.2 ppbv; Hamburg 3.8 ppbv; Sydney 2.1 ppbv; Chicago 2.0 ppbv; Osaka 5.5 ppbv; and Athens 1.6 ppbv (Moschonas and Glavas 1996). Air samples from Kuwaiti houses after the Gulf War (which introduced large amounts of air pollutants from burning oil) showed average *n*-hexane levels of only 4.4 ppbv (Bouhamra 1995).

*n*-Hexane may be expected to comprise around 2% of the VOCs in urban air polluted with hydrocarbons from automobile emissions or other combustion byproducts (Barrefors and Petersson 1993). Close proximity to the exhaust systems of cars or other gasoline-powered vehicles can lead to exposures to

## 5. POTENTIAL FOR HUMAN EXPOSURE

increased concentrations of *n*-hexane. Under rush-hour conditions, the concentrations in the interior air of buses will tend to be lower (55 µg/m<sup>3</sup> or 19.8 ppbv) than the interior levels in cars (69 µg/m<sup>3</sup> or 24.9 ppbv) or the air around persons riding motorcycles (106 µg/m<sup>3</sup> or 38.1 ppbv) (Chan et al. 1994). Transportation tunnels may contain hydrocarbon concentrations around 6 times the levels encountered with ordinary open-air vehicular traffic; this is probably associated with similarly elevated levels of *n*-hexane (Barrefors and Petersson 1993). Measurements of hydrocarbons from vehicular exhaust at the Fort McHenry Tunnel in Baltimore, Maryland have shown *n*-hexane levels just under 60 ppbv (Zielinska et al. 1996).

*n*-Hexane does not seem to be present in tobacco smoke, although such smoke can lead to elevations in the concentrations of other hydrocarbons in the air of interior rooms (Barrefors and Petersson 1993). A complication in such testing is that hydrocarbons in the smoke may have been introduced from sources such as polluted urban air or *n*-hexane from cigarette lighters.

The air in well-ventilated office buildings in urban areas of California contained *n*-hexane levels of approximately 0.55 µg/m<sup>3</sup> (1.5 ppbv) (Daisey et al. 1994). Other studies of heavily polluted urban areas have suggested that the air in offices will have *n*-hexane levels at least an order of magnitude lower than the peak levels in rush-hour traffic in cars or other vehicles (Chan et al. 1994); the same studies showing that the median concentrations averaged over an entire commuting trip are about the same as for the time-averaged median concentrations of *n*-hexane in office buildings (<9 µg/m<sup>3</sup> or <3.2 ppbv).

Research suggests that gases released by various fungi in ductwork, inner walls, and crawl spaces contain a variety of VOCs, including *n*-hexane (Ahearn et al. 1996). Of the total levels of VOCs measured *in situ* from fungal-colonized insulation materials in a 2-year-old office building, *n*-hexane comprised about 2.69% of the total measured VOCs; in air samples collected under laboratory conditions using cultures prepared from fungal isolates, the *n*-hexane contribution to the total measured VOCs was 4.85% (Ahearn et al. 1996). Measurements of the interior air of an office building with fungi in air ducts and fiberglass insulation located in the Houston area showed total VOC concentrations >100 ppbv. The VOCs levels included detectable amounts of *n*-hexane as well as toluene and benzene (Ahearn et al. 1996).

*n*-Hexane was detected in various media (indoor air, groundwater, soil gas, or outdoor air) at 17 vapor intrusion sites evaluated between 2002 and 2009 (Burk and Zarus 2013). Ten of the sites had indoor air measurements, with one site in Hartford, Illinois (IDPH 2002) exceeding the acute- and intermediate-duration indoor air MRLs with a peak indoor air concentration of 12,218 ppb (approximately 43 mg/m<sup>3</sup>).

## 5. POTENTIAL FOR HUMAN EXPOSURE

The Hartford site experienced explosions and fires in homes from vapor intrusion following release of millions of gallons of petroleum to a light nonaqueous layer on groundwater. The groundwater was about 10 feet deep and homes experienced petroleum vapor intrusion following heavy rain events. Streamlined cleanup efforts are still underway at the Hartford site (EPA 2023a).

Concentrations in some workplace settings may be higher than typical ambient air levels. Samples collected in tire factories during the 1970s showed median *n*-hexane levels of 25.9 ppmv around the work area where the rubber curing took place (Van Ert et al. 1980). When workers have assembled items in poorly ventilated rooms, *n*-hexane levels ranging from 500 to 2,500 ppmv have been documented (Iida 1982). Similar workplace findings, usually in countries other than the United States, have been documented, with *n*-hexane concentrations in workspace air in excess of 500 ppmv (Graham et al. 1995). Elevated levels in air are also found in substance misuse cases, where pure *n*-hexane or mixtures containing significant amounts of *n*-hexane are used to produce a “high” (Altenkirch et al. 1977; Graham et al. 1995).

*n*-Hexane is a common trace component in landfill gases at many waste sites (Brosseau and Heitz 1994; O’Leary and Walsh 1995). The *n*-hexane concentrations of these emissions have been documented to range from 3 to 10 mg/m<sup>3</sup> (0.85–2.8 ppm). While these levels would be expected to decrease rapidly as the landfill gases were dispersed into the ambient air, areas near the ground or pockets of air in trenches or excavations could reach levels significantly above the concentrations normally encountered in ambient air. For instance, data averaged over 15-minute intervals during site remediation work at a reclaimed oil refinery site showed levels as high as 121.51 mg/m<sup>3</sup> (34.51 ppmv) in the air around a backhoe digging trench in the petroleum-contaminated soils (Verma et al. 1992). Samples from the same study averaged over a typical 8-hour workshift for the area around the backhoe showed average levels of 3.06 mg/m<sup>3</sup> (0.87 ppmv). Even higher levels (perhaps in excess of 10,000 ppmv) are possible around large spills of *n*-hexane; at such elevated concentrations, as with many components of gasoline-type hydrocarbons, there could be considerable danger from explosions, which are possible when the *n*-hexane levels exceed approximately 1.2% of the volume of air (Budavari et al. 1989). Since 0.1% by volume is equivalent to 1,000 ppmv, this flash-point level for *n*-hexane would be at a level of ≥12,000 ppmv.

*n*-Hexane is a pollutant monitored in the national Air Quality System (AQS) database, which contains ambient air pollution data collected by EPA, state, local, and tribal air pollution control agencies from monitors throughout the country. Table 5-8 shows the yearly mean 24-hour percentile distributions of *n*-hexane at monitoring stations across the United States.

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-8. Summary of Annual Concentration of *n*-Hexane (ppbv) Measured in Ambient Air at Locations Across the United States<sup>a,b</sup>**

Year	Number of monitors	Number of samples	Average of the arithmetic mean at all locations	Maximum concentration
2018	105	5,776	0.18	49.2
2019	71	4,038	0.21	33
2020	85	4,928	0.49	141
2021	81	6,326	0.77	955
2022	64	1,597	0.25	50
2023	55	1,110	0.99	278

<sup>a</sup>Values were originally reported in parts per billion carbon (ppbC) and converted to ppbv by dividing by the number of carbons in *n*-hexane.

<sup>b</sup>24-hour sampling period.

Source: EPA 2024

### 5.5.2 Water

In general, data on levels in water or groundwater are very limited, with only a little bit of information available in the literature. *n*-Hexane was identified as a contaminant in well water from the Upper Potomac aquifer (DeWalle and Chian 1981). *n*-Hexane was identified in all eight sites with values between 0.6 and 4.7 µg/L, with a median value of 1.4 µg/L (determined using ATSDR's SHOWER model, discussed in Section 5.6). In another study on surface water in the Gulf of Mexico (Sauer et al. 1978), *n*-hexane was identified in five of eight sites with values between 1.5 and 7.8 ng/L.

*n*-Hexane is highly volatile and typical treatment techniques for drinking water supplies in larger towns and cities would be expected to volatilize the *n*-hexane before it could enter the distribution system. It is likely that some *n*-hexane would be found in groundwater contaminated by gasoline leaks from underground storage tanks (UST). This could be a matter of concern for some domestic groundwater wells used for drinking water supplies. Since the emphasis in UST programs is usually on the more soluble aromatic fractions (e.g., benzene) or on bulk measurements of TPHs (Potter 1993), no information could be identified in the literature dealing explicitly with *n*-hexane.

## 5. POTENTIAL FOR HUMAN EXPOSURE

### 5.5.3 Sediment and Soil

Very little information could be identified dealing with *n*-hexane levels in sediments and soils. *n*-Hexane has been identified among the contaminants in an offsite oilfield-disposal pit in New Mexico (Eiceman et al. 1986). Since *n*-hexane is a trace constituent of crude oil and natural gas, as well as a component of refined petroleum products, soil or sediment contamination with *n*-hexane can be expected near oilfield production sites, large soil spills, slush pits and other areas around refineries, and in waste sites where petroleum products or other *n*-hexane-containing wastes had been disposed. Detections would also be likely near many tank storage facilities, pipelines, truck or rail transfer sites, car repair facilities, automobile assembly or storage facilities, and auto and truck fueling facilities (DeLuchi 1993).

At many waste sites, *n*-hexane has been detected in the landfill gases vented from the soils at the disposal sites (Brosseau and Heitz 1994; O'Leary and Walsh 1995). While information in the literature is extremely limited, trace levels of *n*-hexane are probably found in the soils or the soil gases at many waste disposal sites.

### 5.5.4 Other Media

Testing for alkanes is often directed at compounds less volatile (e.g., C10 or higher) than *n*-hexane (Hernandez et al. 1995). There is, therefore, limited information in the literature on the levels of *n*-hexane encountered in foodstuffs. Analyses carried out in the 1960s and 1970s would have sometimes involved analytical methods not considered accurate by contemporary standards. Caution is also needed in interpreting published results to make sure the testing did not involve materials that had not yet gone through the complete cycle of solvent recovery, heating, and final vacuum treatment to recover the *n*-hexane solvent and remove as much as possible of this hydrocarbon from the final product intended for human consumption. Before these recovery processes, the crude oil or meal products can be expected to show appreciably high levels of *n*-hexane. In studies of fully processed edible oil products carried out in the 1960s, it was determined that *n*-hexane residues were generally at levels <10 ppm (Watts and Holswade 1967). Investigations using more precise modern analysis techniques (Hautfenne et al. 1987) concluded that residual *n*-hexane residues for refined food products would be <2 ppm. If the standard assumption of 80 g of fat consumed per 70-kg person per day is made, such residual levels would be the equivalent of no more than 2.29 µg/kg/day of *n*-hexane, which is a toxicologically insignificant amount.

## 5. POTENTIAL FOR HUMAN EXPOSURE

*n*-Hexane is present in a variety of products commonly used in household settings. Given its volatility, this creates possibilities for exposures from inhalation as well as by dermal contact and ingestion. In a study of >1,000 common household products, *n*-hexane was detected in 101 products. *n*-Hexane was detected in >10% of the items sampled in the following product categories: automotive products; oils, greases, and lubricants; and adhesive-related products (Sack et al. 1992).

### 5.6 GENERAL POPULATION EXPOSURE

Low-level exposures to *n*-hexane may occur for much of the U.S. population, especially those who live in urban areas or those that commute in areas with heavy traffic, due to emissions of *n*-hexane associated with motor fuel use. As such, the general population will be exposed to very low levels at all times, while those living in urban centers may be exposed to slightly higher levels. *n*-Hexane blood levels have been measured in National Health and Nutrition Examination Survey (NHANES) samples beginning in 2009–2010; however, the levels were below the detection limit of 0.122 ng/mL.

ATSDR's three-compartment Shower and Household-Use Exposure (SHOWER) model predicts air concentrations in the shower stall, bathroom, and main house throughout the day by estimating the contribution from showering or bathing and the contribution from other water sources in the house, such as the dishwasher, clothes washer, and faucets. This information along with human activity patterns are used to calculate a daily time-weighted average exposure concentration via inhalation exposure and from dermal uptake from skin contact. ATSDR's SHOWER model is available by sending a request to showermodel@cdc.gov. Using median treated water levels as discussed in Section 5.5.2 (1.4 ng/L, based on DeWalle and Chian 1981) and representative outdoor air levels discussed in Section 5.5.1 (EPA 2024) reasonable maximum exposure (RME) levels for *n*-hexane were calculated for different exposure groups (Table 5-9) (ATSDR 2022b).

**Table 5-9. Reasonable Maximum Exposure Daily Inhalation Dose in µg/kg/day and Administered Dermal Dose of *n*-Hexane for the Target Person**

Exposure group	Inhalation	Dermal
Birth-<1 year	0.22	0.018
1-<2 years	0.24	0.016
2-<6 years	0.15	0.014
6-<11 years	0.085	0.011
11-<16 years	0.057	0.0093
16-<21 years	0.044	0.0085

## 5. POTENTIAL FOR HUMAN EXPOSURE

**Table 5-9. Reasonable Maximum Exposure Daily Inhalation Dose in µg/kg/day and Administered Dermal Dose of n-Hexane for the Target Person**

Exposure group	Inhalation	Dermal
Adult	0.039	0.0083
Pregnant and breastfeeding women	0.056	0.0084

Source: ATSDR 2022b

## 5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

In addition to individuals who are occupationally exposed to *n*-hexane, there are several groups within the general population that have potentially high exposures (higher than background levels) to *n*-hexane. These populations include individuals living near *n*-hexane production or disposal sites. Individuals who subject themselves to substance misuse by inhaling *n*-hexane or vapors from products containing significant levels of *n*-hexane would also experience potentially high exposure levels (Altenkirch et al. 1982; Graham et al. 1995).

Work situations where *n*-hexane is used as a solvent or in adhesives and where there are very poor ventilation conditions could also have elevated exposure risks. Workers in poorly ventilated confined areas (e.g., warehouses, garages, tunnels) or trenches where *n*-hexane levels could build up from engine exhaust or from off-gassing, as in some landfill sites, might also experience higher exposures. Likewise, workers in tire-manufacturing facilities may have a heightened potential for health hazards since the rubber vulcanization process can involve exposures to *n*-hexane (Graham et al. 1995). Vehicle repair technicians that use an aerosol solvent product containing *n*-hexane, acetone, and toluene may also be exposed to elevated levels. A study of such workers reported exposure “pulses” with an average breathing zone VOC level of 394 mg/m<sup>3</sup> from the solvent formulation (Wilson et al. 2007).