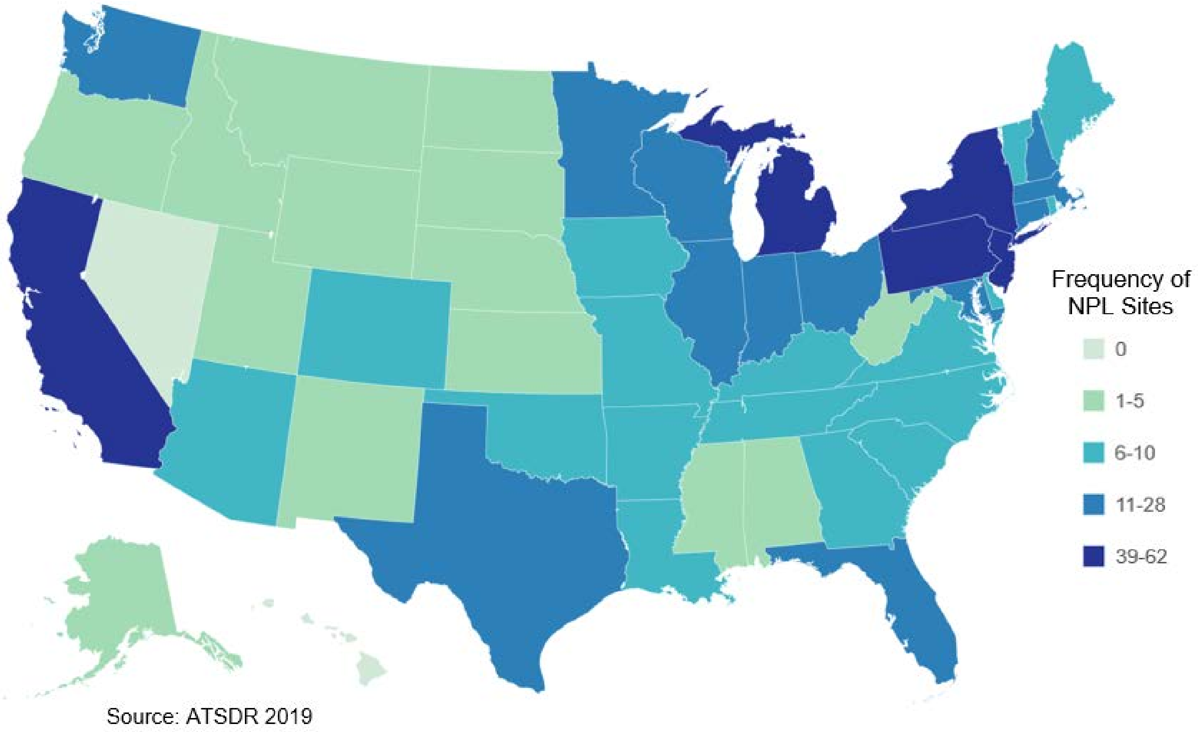
CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Acetone has been identified in at least 652 of the 1,867 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2019). However, the number of sites in which acetone has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 646 are located within the United States, 4 are located in Puerto Rico, 1 is located in Guam, and 1 is located in the Virgin Islands (not shown).

Figure 5-1. Number of NPL Sites with Acetone Contamination



Source: ATSDR 2019

- Exposure to acetone primarily occurs by inhaling ambient air and by ingesting drinking water and food containing acetone, and can also be created as an endogenous metabolite. Acetone occurs naturally and from anthropogenic sources.

- Workers in certain industries, such as certain paint, plastic, artificial fiber, and shoe factories are likely exposed to much higher levels of acetone than the general population. Professional painters, commercial and household cleaners, smokers, frequent users of nail polish removers, and people who live near certain landfill sites (emitting higher than ambient levels of acetone) or other industrial sources of emission are also susceptible to higher exposure concentrations of acetone.

- Acetone is used primarily as an intermediate in chemical production and as a solvent.
- Reaction with hydroxyl radicals and photolysis are important fate processes in the atmosphere. Acetone has a reasonably long half-life in air and is transported long distances from its source of emission.
- The most important fate determining process for acetone in water, sediment, and soil is biodegradation. The important transport processes of acetone in soil are volatilization to the atmosphere and leaching into groundwater.

Acetone is emitted into the atmosphere both from natural and anthropogenic (human-made) sources. Natural sources of emission include plants and trees (Graedel et al. 1986; Isidorov et al. 1985; Khalil and Rasmussen 1992), volcanic eruptions (Isidorov et al. 1990), forest fires (Graedel et al. 1986), and insects and microbes (Graedel et al. 1986). Acetone is also produced endogenously and expired in human breath (Conkle et al. 1975). Some important anthropogenic sources of acetone in the air include vehicular exhaust (Graedel et al. 1986), chemical manufacturing (Graedel et al. 1986), tobacco smoke (Manning et al. 1983), wood burning and pulping (Graedel et al. 1986), refuse and polyethylene combustion (Graedel et al. 1986; Hodgkin et al. 1982; NAS 1976), petroleum production (Graedel et al. 1986), certain landfill sites (Hodgson et al. 1992; LaRegina et al. 1986), and solvent use (Graedel et al. 1986). The sensitized photoreaction of dissolved organic matter naturally produces acetone in seawater (Mopper and Stahovec 1986). Chemical manufacturing industries (EPA 1975), energy-related industries (Mohr and King 1985), and user industries (EPA 1975) release acetone to surface waters. Acetone is released into groundwater mainly as a result of leaching from municipal and industrial landfills (Brown and Donnelly 1988). The principal sources of acetone in soil are municipal and industrial discharge in landfills (EPA 1988b). Another source is atmospheric deposition (Grosjean and Wright 1983). Acetone is released in soil from natural sources, such as disposed agricultural and food wastes and animal wastes (Graedel et al. 1986).

The two processes that are important in determining the fate of acetone in the atmosphere are reaction with hydroxyl radicals and photolysis. The estimated half-life of acetone in the air due to combinations of these two reactions is 22 days (Meyrahn et al. 1986). Because of this reasonably long half-life, acetone is transported long distances from its source of emission. Wet deposition transports atmospheric acetone to surface water and the terrestrial surface (Grosjean and Wright 1983).

The most important fate determining process for acetone in water is biodegradation (Rathbun et al. 1982). Because of its high-water solubility, acetone does not adsorb significantly to sediment and suspended solids in water. The log K_{ow} value of -0.24 (see Table 4-2) suggests that bioconcentration of acetone in aquatic organisms is not significant. In addition, one study found that acetone does not appreciably bioconcentrate in adult haddock (Rustung et al. 1931). Based on these data, acetone is not expected to biomagnify in aquatic or terrestrial food chains.

Biodegradation is the most important degradative process for acetone in sediment and soil (Rathbun et al. 1982). The important transport processes of acetone in soil are volatilization to the atmosphere and leaching into groundwater.

The levels of acetone in ambient air and water are generally low. The concentration of acetone in the atmosphere in remote areas is <1 ppb v/v (1 ppb=0.001 ppm) (Cavanagh et al. 1969; Arnold et al. 1986). Its mean concentration in the atmosphere of rural areas is <3 ppb (Shepson et al. 1991; Snider and Dawson 1985). The mean concentration of acetone in urban air in the United States is 6.9 ppb (Shah and Singh 1988; Li et al. 2018) but has been reported as low as 1.8 ppb (4.19 μg/m^3) (Liu et al. 2006).

Indoor air tends to have a higher concentration of acetone than outdoor air in the United States due to the use of household consumer products. A study of 100 homes in New Jersey reported a mean indoor air acetone concentration of 36.1 ppb (Weisel et al. 2008). In comparison, a study of 17 outdoor air samples across the United States reported a mean outdoor air acetone concentration of 6.9 ppb (Shah and Singh 1988). Homes with tobacco smokers also tend to have higher indoor air acetone concentrations than homes without tobacco smokers (20.8 versus 29.5 ppb) (Heavner et al. 1996).

The concentration of acetone in open ocean 200 m deep near the Bahamas was 0.35 ppb (Kieber and Mopper 1990). The concentration of acetone in the Potomac River in Virginia was below the detection limit of 40 ppb (Hall et al. 1987), and the level will be higher in water receiving industrial and municipal discharges containing acetone. An industrial landfill leachate in Michigan contained 62 ppm acetone (Brown and Donnelly 1988). A drinking water well in New Jersey that drew water from a contaminated aquifer had an acetone concentration of 3,000 ppb (Burmaster 1982). The concentration in drinking water from Seattle, Washington, was 1 ppb (Keith et al. 1976). A concentration of 6 ppb acetone was detected in the sediment of a creek adjacent to a landfill in Louisville, Kentucky (Stonebraker and Smith 1980). Acetone has been detected in the volatile components of several fruits and vegetables (Bartley and Schwede 1989; Lovegren et al. 1979).

The general population is exposed to acetone by inhaling ambient air, by ingesting drinking water and food containing acetone, and by using consumer products such as nail polish remover. No data for the total daily intake of acetone for the general population were located. However, there are data that workers in certain industries, such as certain paint, plastic, artificial fiber, and shoe factories are exposed to high levels of acetone (Kawai et al. 1990a; Pezzagno et al. 1986). Professional painters, and commercial and household cleaners are also likely to be exposed to higher acetone concentrations than the general population. Among the general population, smokers, frequent users of nail polish removers (including beauty salon workers), and people who live near certain landfill sites (emitting higher than ambient levels of acetone) or other industrial sources of emission are susceptible to higher exposure concentrations of acetone.

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

Approximately 90% of acetone in the United States is manufactured by cumene peroxidation (ICIS 2017). In the peroxidation process, cumene is oxidized to a hydroperoxide, which is cleaved to yield acetone and phenol (Zakoshansky and Griaznov 1995). In the past, acetone was also commonly manufactured using isopropyl alcohol, which is catalytically dehydrogenated to yield acetone and hydrogen (ICIS 2017); however, this method has declined in use (ICIS 2017). Acetone may also be produced via the oxidation of propylene oxide (ICIS 2017).

No information is available in the TRI database on facilities that manufacture or process acetone because this chemical is not required to be reported under Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986) (EPA 2005). As of 2020, facilities that release 5,000 or more pounds of acetone into the atmosphere must report these releases (EPA 2020).

5.2.2 Import/Export

In the period from 2014 to 2018, general imports and imports for consumption of acetone were equal. General imports are total physical arrivals of acetone to the United States from other countries that either enter consumption channels immediately or enter into bonded warehouses or Foreign Trade Zones (FTZs) (US Census 2018). A bonded warehouse is an approved private warehouse used to store imports until duties or taxes are paid (US Census 2018). FTZs are specially licensed commercial and industrial areas in or near ports of entry where goods may be brought in without paying customs duties. Imports brought to FTZs can be manipulated (e.g., sold, stored, exhibited, repacked, cleaned, manufactured) prior to reexport or entry (US Census 2018). U.S. imports of acetone fluctuated from 2014 to 2018, ranging from 93,639,132 kg in 2016 to 231,998,897 kg in 2018 (USITC 2019). Imports for consumption are the total amount of merchandise that has physically cleared through customs by either entering consumption channels immediately or leaving bonded warehouses or FTZs (US Census 2018). Both domestic exports and total exports of acetone fluctuated from 2014 to 2019 as well. U.S. domestic exports of acetone range from 159,620,412 kg in 2014 to 106,882,376 kg in 2018 (USITC 2019). Total exports range from 185,605,919 kg in 2015 to 118,081,807 kg in 2016 (USITC 2019). In 2018, there were 119,040,276 kg of total exports of acetone (USITC 2019).

5.2.3 Use

Acetone is used primarily as an intermediate in the chemical production of methyl methacrylate and bisphenol A (ICIS 2017). It is also commonly used as a solvent, particularly in the pharmaceutical industry (ICIS 2017). Additional uses of acetone include the manufacture of other chemicals such as methyl isobutyl ketone (ICIS 2017).

According to Chemical Data Reporting (CDR), acetone is used for personal care products; paints and coatings; adhesives and sealants; fabric, textile, and leather products; toys, playground, and sporting equipment; automotive care products; building/construction materials; as a chemical intermediate; in cleaning and furnishing care products; electrical and electronic products; lubricants and greases; metal products; plastic and rubber products; and water treatment products consumer and commercial product categories (CDR 2012, 2016). CDR data on industrial uses include acetone utilization as solvents which become part of the product formulation or mixture, intermediates, solvents for cleaning and degreasing, non-pesticidal agricultural chemicals, paper waterproofing, surface active agents, photosensitive chemicals, functional fluids (closed systems), laboratory chemicals, processing aids specific to petroleum production, a formulated mixture for automotive refinishing, paint additives and coating additives, ion exchange agents, fuels and fuel additives, viscosity adjustors, adhesives and sealant chemicals, and processing aids not otherwise listed (CDR 2012, 2016). Additionally, acetone may be used as a flavoring agent or solvent in food products (FDA 2019).

5.2.4 Disposal

A small amount of acetone is regenerated from solvent wastes produced during its use by reclaiming processes (Kupferschmid and Perkins 1986). Acetone can be removed from wastewater by air stripping

(PubChem 2021), but the vapor-phase acetone generated during stripping requires a suitable disposal method. The three methods commonly used for the disposal of waste containing acetone are underground injection, burial in sanitary landfills, and incineration. The underground injection of acetone-containing waste is allowed under the amended Section 148.10 of Code of Federal Regulations (EPA 1991). The land disposal of wastewaters containing spent acetone is allowed under Section 268.41 of the Code of Federal Regulations as long as the concentrations of acetone and other permissible spent cosolvents in the waste do not exceed 0.05 and 0.59 mg/L, respectively (EPA 1988a). Incineration under controlled conditions (to attain complete combustion) is one of the better methods of disposal for acetone, and incineration is easier when acetone is mixed with a more flammable solvent. The suitable methods for the destruction of acetone are fluidized bed incineration at a temperature of 450–980°C with residence times of seconds or rotary kiln incineration at 820–1,600ºC with residence times of seconds (PubChem 2021).

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

Acetone is emitted into the atmosphere both from natural and anthropogenic sources. Natural sources of emission include plants and trees. Acetone has been detected in a number of plant volatiles including onions, tomatoes, watermelon, nectarines, beans, and cannabis (Wang et al. 2019; Lewinsohn et al. 2005; Lovegren et al. 1979; Takeoka et al. 1988; Turner et al. 1980), and emissions have been detected from a variety of trees including willow, aspen, birch, balsam poplar, oak, fir, pine, juniper, cedar, and cypress (Isidorov et al. 1985; Khalil and Rasmussen 1992). Acetone is produced endogenously and released as a component of human breath (Conkle et al. 1975; Krotoszynski 1977; Trotter et al. 1971). Volatiles from animal wastes, microbes, and insects are also examples of natural sources of acetone in the air (Graedel et al. 1986). In addition, forest fires and volcanic eruptions emit acetone into the atmosphere (Graedel et al. 1986; Isidorov et al. 1990). Approximately three-quarters of acetone emissions to air are expected to be a result of natural sources (Jacob et al. 2002). Prior to 2020, EPA (2005) did not require information on releases of acetone to the atmosphere from manufacturing and processing facilities. As of 2020, EPA requires that facilities must report atmospheric releases of acetone over 5,000 pounds (EPA 2020). However, no information of atmospheric releases of acetone have been reported to date. Still, acetone is one of the most common substances found at Superfund sites (EPA 1999).

Some important anthropogenic sources of acetone in the air are automobile and diesel exhaust (Inomata et al. 2013; Jacob et al. 2002; Song et al. 2010; Wang et al. 2020), biomass burning (Akagi et al. 2011; Jacob et al. 2002; Singh et al. 1994), chemical manufacture (Graedel et al. 1986), tobacco smoke (Manning et al. 1983), wood burning and pulping (Graedel et al. 1986; Kleindienst et al. 1986; Lipari et al. 1984), polyethylene burning (Hodgkin et al. 1982), refuse combustion (NAS 1976), petroleum production (Graedel 1978), certain landfill sites (Hodgson et al. 1992; LaRegina et al. 1986; Militana and Mauch 1989), and solvent uses (De Medinilla and Espigares 1988). Acetone is also formed in the atmosphere from the photochemical oxidation of propane, i-butane, and i-pentane (Arnold et al. 1986; Pozzer et al. 2010; Singh and Hanst 1981) and possibly from propylene oxide and epichlorohydrin (EPA 1985a). Atmospheric emissions are also likely from several consumer products including nail polish removers, particle board (Tichenor and Mason 1988), carpet backing (Hodgson et al. 1993), some paint removers (EPA 1986), and a number of liquid/paste waxes or polishes (Knoppel and Schauenburg 1989; Sack et al. 1992). Certain detergents/cleansers (Knoppel and Schauenburg 1989; Sack et al. 1992), adhesives, and carburetor and choke cleaners (EPA 1989) are also known to contain acetone.

Assessing levels of acetone requires strict quality assurance practices because environmental air samples can be inadvertently contaminated during laboratory preparation (EPA 2020).

5.3.2 Water

There is no information on releases of acetone to water from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005).

Acetone is released into surface water as wastewater from certain chemical manufacturing industries (Gordon and Gordon 1981; Hites and Lopez-Avila 1980; Jungclaus et al. 1978). It is also released in water from energy-related industries, such as coal-gasification (Mohr and King 1985; Pellizzari et al. 1979) and oil shale processing (Hawthorne and Sievers 1984; Pellizzari et al. 1979). Acetone was found in 27 of 63 effluent waters from a wide range of chemical industries in the United States (EPA 1979). A survey of industrial effluents indicates that acetone was detected in effluents from various industrial products such as paper, plastic, pharmaceutical, specialty cleaning and polishing products, paint and allied products, gum and wood chemicals, cyclic intermediates, industrial organic chemicals, gypsum products, and paper board products (EPA 1975).

Acetone is released to groundwater as a result of leaching from municipal and industrial landfills (Brown and Donnelly 1988; Connecticut Agricultural Experiment Station 1986; Gould et al. 1983; Steelman and Ecker 1984; Stonebraker and Smith 1980). Leaching from polyethylene distribution pipes may be a source of acetone in drinking water (Anselme et al. 1985). One of the sources of acetone in seawater is the sensitized photoreaction of dissolved organic matter (Mopper and Stahovec 1986).

5.3.3 Soil

There is no information on releases of acetone to soil from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005).

Acetone leaches readily in soil (see Section 5.5.3). Therefore, the detection of acetone in leachate and groundwater from municipal and industrial landfills indicates the source of acetone in landfill soils is municipal and industrial waste. Zhang et al. (2012) showed that acetone is one of the top five ketones released from raw and aerobically treated municipal solid waste during anaerobic degradation during a simulated landfilling study. Other sources of acetone released into soil include disposal of agricultural and food waste, animal wastes (see Section 5.3.1), and atmospheric wet deposition. Household septic tank effluents are another source of acetone in soil because they can contain acetone and are discharged into the soil (EPA 1985b).

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

Air. Organic compounds with ambient vapor pressure $>10^{-4}$ mmHg should exist almost entirely in the vapor phase (Eisenreich et al. 1981). Because the vapor pressure of acetone is 231 mmHg at 25°C (see Table 4-2), acetone should exist exclusively in the vapor phase in the atmosphere. Furthermore, the collection methods used for the quantification of acetone in the atmosphere (Jarke et al. 1981; Juttner 1986; LaRegina et al. 1986) indicate that atmospheric acetone exists as vapor. Due to the atmospheric half-life, which is on the order of days (see Section 5.4.2), acetone will be transported long distances in the air. Although not a large sink (Chatfield et al. 1987), small amounts of acetone will be removed from the atmosphere by wet deposition (Grosjean and Wright 1983), which will transport acetone from the atmosphere to surface water and soil. Due to its relatively low Henry's law constant, acetone should tend to diffuse from air to water, and studies have concluded that the atmosphere is a potential source of acetone to streams (Kenner et al. 2014; Pankow et al. 2006). While acetone may be released to the air from the ocean, Marandino et al. (2005) suggest that the ocean is more important as a sink for acetone, while Fischer et al. (2012) suggest that Northern Hemisphere oceans are sinks while tropical oceans are sources of acetone to the atmosphere. Other sinks include oxidation by OH, photolysis, and dry deposition, which may remove up to 95 Tg of acetone per year from the atmosphere (Jacob et al. 2002; Singh et al. 1994).

Water. The complete miscibility of acetone in water suggests that partitioning of acetone from the water column to sediments and suspended solids in water is not significant. The estimated low value of 0.73 for log K_{oc} (see Table 4-2) also suggests that adsorption of acetone to sediments and suspended solids is not significant. In the absence of water, acetone vapor adsorbs rather strongly to the clay component of soil by hydrogen bonding (Goss 1992; Steinberg and Kreamer 1993). The sorption is dependent on relative humidity, and increasing the humidity decreases sorption drastically. In water-saturated soil or sediment, only organic carbon, as indicated by K_{oc}, (and not hydrogen bonding) may control the sorption of acetone (Steinberg and Kreamer 1993). Experimental adsorption studies with kaolinite, montmorillonite, and stream sediments showed very little or no loss of acetone from water to the adsorbents (Rathbun et al. 1982). The transport of acetone from the water column to the atmosphere depends on the Henry's law constant. The Henry's law constant for acetone is 3.97×10^{-5} atm-m^3/mole (see Table 4-2). Therefore, volatilization of acetone from water, although not very fast, is significant (Thomas 1990). The volatilization rate of a chemical depends on the characteristics of the chemical and the water and on other ambient conditions (e.g., water depth, suspended solid concentration, water current, wind speed, temperature). Based on an estimation method (Thomas 1990) and a Henry's law constant value of 4.26x10^{-5} atm-m^3/mole, the volatilization half-life of acetone from a model river 1 m deep, flowing at a current of 1 m/second with a wind velocity of 3 m/second is about 18 hours. The mean volatilization coefficient for acetone in a model outdoor stream ranged from 7.15x10^{-4} to 14.8x10^{-4}/minute (Rathbun et al. 1989, 1991). Therefore, the volatilization half-life of acetone from the model stream is in the range of 7.8–16.2 hours. It was concluded that volatilization dominates the fate of acetone in water (Rathbun et al. 1989, 1991). Results of a laboratory study (Rathbun et al. 1982) also concluded that volatilization is one of the important fate-determining processes for acetone in streams.

Sediment and Soil. The two significant transport properties for acetone in soil are volatilization and leaching. Leaching transports acetone from soil to groundwater. The rate of leaching from soil by rainwater depends on the conditions in the soil. Because acetone has a low K_{oc} value, sorption of acetone in water-saturated soil will be weak. The low retention ability will permit acetone to leach into groundwater. A sorption study with moist clay soils indicates that aqueous acetone causes swelling in these soils (Green et al. 1983), and this process may allow the retention of a small fraction of acetone. Groundwater monitoring studies (see Section 5.4.2) at landfill sites provided evidence of the importance of acetone leaching from soil. Volatilization transports acetone from soil to the atmosphere. The volatility rate of acetone from soil depends on the soil characteristics (moisture content, soil porosity, etc.). Because the acetone is weakly sorbed to soil, the volatility depends primarily on the moisture content of the soil. In dry soil, the volatilization rate from soil surfaces is high due to the high vapor pressure of acetone. In moist soil, the rate of volatilization tends toward that of acetone in water, which depends on the Henry's law constant. Acetone volatilizes moderately under these conditions. The detection of acetone at higher concentrations in downwind air of a landfill site, compared to upwind air (Militana and Mauch 1989), supports the importance of volatilization as a transport process in soil.

No data regarding the transport of acetone from soil to plants were located.

Other Media. The log K_{ow} value of -0.24 (see Table 4-2) suggests that bioconcentration of acetone in aquatic organisms is not significant. The measured bioconcentration factor for adult haddock exposed to acetone under static conditions at 7–9°C was <1 (Rustung et al. 1931). No data regarding the biomagnification potential of acetone in aquatic organisms were located; however, the low K_{ow} value suggests that biomagnification from animals of lower to higher trophic levels is unlikely.

5.4.2 Transformation and Degradation

Air. The reactions of acetone vapor with nitrogen oxides, hydroxyl radicals (OH), singlet molecular oxygen ($^1\Delta_g$, singlet atomic oxygen (O[^{3}P]), and nitrate radicals have been studied. Given the second order rate constants for the reactions of acetone with $^1\Delta_g$ (Datta and Rao 1979) and O(^{3}P) (Lee and Timmons 1977; Singh et al. 1994), and the concentrations of singlet molecular and atomic oxygen in the atmosphere (Graedel 1978), these reactions are insignificant in determining the fate of acetone in the atmosphere. The reaction of acetone with nitrate radicals in the atmosphere was also determined to be insignificant (Boyd et al. 1991). Smog chamber studies with acetone and nitrogen oxides conclude that acetone has low reactivity in terms of ozone and nitrogen dioxide formation and that the rate of disappearance of acetone by this process is low (Altshuller and Cohen 1963; Dimitriades and Joshi 1977; Yanagihara et al. 1977). The photochemical oxidation of acetone in the presence of nitrogen oxides produces small amounts of peroxyacetic acid and peroxyacetyl nitrate (Hanst and Gay 1983). In a self-made chamber, experiments with and without NaCl, $(NH_4)_2SO_4$, and $NaNO_2$ showed that acetone is not capable of forming secondary organic aerosols (Ge et al. 2017).

The two significant processes in determining the fate of acetone in the atmosphere are reaction with hydroxyl radicals and photolysis. The rate constant for the reaction of hydroxyl radicals with acetone at 25°C is in the range of 1.8–5.0x10^{-13} cm^3/molecule-second (Cox et al. 1980, 1981; PubChem 2021; Meyrahn et al. 1986). The estimated average lifetime of acetone due to reaction with hydroxyl radicals is 44.5 days (Meyrahn et al. 1986). The probable pathways for the reaction of acetone with hydroxyl radicals in the troposphere have been postulated, and methylglyoxal is the primary product of this reaction (Altshuller 1991). Acetone underwent significant photolysis with an artificial light of maximum emission at 300 nm (near-ultraviolet UVB) (Fujiki et al. 1978). Besides free radicals, the primary products of acetone photolysis in sunlight are carbon dioxide and acetylperoxynitrate (Altshuller 1991). The lifetimes of acetone due to photolysis under cloudless conditions at 40°N latitude and sea level during winter and summer are estimated to be 83 and 19 days, respectively (Martinez et al. 1992). The estimated average lifetime of acetone at 40°N due to combined hydroxyl radical reaction and photolysis is 32 days (Meyrahn et al. 1986), corresponding to a half-life of 22 days. Jacob et al. (2002) has estimated a mean tropospheric lifetime of 15 days. The lifetime of acetone in the upper troposphere increases with altitude and ranges from 10–20 days in the tropics to 75–250 days at mid-latitudes (Arnold et al. 2004). Due to the pressure dependence of the quantum yield, the rate of photodissociation will increase as altitude increases, whereas the reaction rate with hydroxyl radicals will decrease because temperature decreases at higher altitudes. Therefore, the lifetime of acetone in the atmosphere will remain approximately constant with respect to altitude. However, the rate will show a pronounced dependence on latitude with greater losses of acetone occurring near the equator, compared to the poles (Meyrahn et al. 1986).

Water. Based on the rate constant for the reaction of acetone with hydroxyl radicals in water at pH 7 ($5.8–7.7x10^7$/M-second) (Anbar and Neta 1967) and the concentration of hydroxyl radicals in eutrophic waters ($3x10^{-17}$ M) (Mill and Mabey 1985), this reaction will not be significant in water. When distilled water or natural water containing acetone was exposed to sunlight for 2–3 days, no photodecomposition of acetone was observed (Rathbun et al. 1982). Therefore, photolysis of acetone in water is not an important process.

Many aerobic biodegradation screening studies with mixed microorganisms from waste-treatment plant effluents, activated sludge, or sewage have examined the biodegradability of acetone (Babeu and Vaishnav 1987; Bridie et al. 1979; EPA 1990; Ettinger 1956; Gaudy et al. 1963; Hatfield 1957; Heukelekian and Rand 1955; Lamb and Jenkins 1952; Price et al. 1974; Stafford and Northup 1955; Thom and Agg 1975; Urano and Kato 1986a, 1986b). These studies indicate that acetone is easily biodegradable with acclimatized microorganisms or after a suitable lag period (≈1 day) (Urano and Kato 1986a, 1986b), as long as the initial concentration of acetone is not at a toxic level. For example, acetone at a concentration of 500 mg/L was toxic to microorganisms when biooxidation of acetone by activated sludge was attempted (Gerhold and Malaney 1966). Biodegradation of acetone was much slower in seawater than in fresh water (Takemoto et al. 1981). After a suitable lag period (5 days), acetone biodegraded quantitatively under anaerobic conditions with anaerobic acetate enriched culture medium (Chou et al. 1978). A biodegradation study of acetone in natural water collected from Lago Lake near Athens, Georgia, determined that the biodegradation kinetics are multiphasic in nature and depend on the substrate concentration. The determined rate of degradation was faster at higher initial concentrations (the maximum concentration used was 0.5 mg/L) (Hwang et al. 1989).

In a laboratory experiment with natural stream water and sediment, no acetone was lost in 338 hours under sterile conditions in closed flasks. However, with nonsterile natural sediment, 100% of the acetone was lost in 500 hours following a lag period of 90 hours (Rathbun et al. 1982). The authors of this study concluded that biodegradation was one of the important processes for the loss of acetone in streams. Significant loss of acetone due to biodegradation was not observed in a later study where acetone was injected continuously in an outdoor model stream (Rathbun et al. 1988, 1989, 1991, 1993). Attempts to induce biodegradation by adding glucose and a nutrient solution containing bacteria acclimated to acetone were unsuccessful. The authors concluded that the residence time of acetone in the model stream

(6 hours) was too short for the bacteria to become acclimated in the water before initiation of biodegradation. However, this explanation may not be valid if attached bacteria, rather than free-floating bacteria, dominate the biodegradation process. As an alternative explanation, the study authors indicated that low levels of nitrate in the model stream may be responsible for the lack of acetone biodegradation.

Sediment and Soil. The biodegradation studies for water discussed above indicate that biodegradation of acetone in sediment and soil will be significant. No evidence was located to suggest that any degradation process other than biodegradation is important in sediment and soil. However, laboratory or field data examining the biodegradability of acetone in soil are lacking. One study of soil from a natural gas company isolated a gram-negative bacterium *(Paracoccus solventivorans)* capable of degrading acetone (Siller et al. 1996).

5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to acetone depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of acetone 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 acetone 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 5-1 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 5-2.

Table 5-1. Lowest Limit of Detection Based on Standards[a]

Media	Detection limit	Reference
Air (occupational)	0.006 ppm	NIOSH 2017
Air (occupational)	<0.01 ppm	Campbell and Moore 1979
Air (indoor and outdoor)	0.013 ppb	Zhu et al. 2005
Water	0.5 mg/L	Rahim and Basir 1981
Groundwater	0.01 mg/L	USGS 2001
Fresh and seawater	0.03 µg/L	Kieber and Mopper 1990

Table 5-1. Lowest Limit of Detection Based on Standards[a]

Media	Detection limit	Reference
Industrial runoff	100 µg/L	Line et al. 1997
Sediment and soil	100 µg/kg	EPA 1996

[a] Detection limits based on using appropriate preparation and analytics. These limits may not be possible in all situations.

Table 5-2. Summary of Environmental Levels of Acetone in the United States

Media	Low	High	For more information
Outdoor air (ppbv)	80	4,700	Table 5-5
Indoor air (ppbv)	1.2	8,732	Table 5-6
Surface water (ppb)	14	53	Table 5-8
Ground water (ppb)	0	42,000	Section 5..5.2
Drinking water (ppb)	<6	68.36	Table 5-9
Food (ppb)	0.1	880	Section 5.5.4
Soil	1	5,300	Section 5.5.3

Detections of acetone in air, water, and soil at NPL sites are summarized in Table 5-3.

Table 5-3. Acetone Levels in Water, Soil, and Air of National Priorities List (NPL) Sites

Medium	Median[a]	Geometric mean[a]	Geometric standard deviation[a]	Number of quantitative measurements	NPL sites
Water (µg/L)	280	528	28.2	174	119
Soil (mg/kg)	1.10	2.03	54.2	133	100
Air (ppb)	22.2	30.7	12.2	42	29

[a] Concentrations found in ATSDR sites measured at 1,867 NPL sites between 1981 and 2019 (ATSDR 2019). 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

Acetone is a volatile compound and is stable in air. Ambient air pollution data is collected by EPA as well as state, local, and tribal air pollution control agencies in the U.S. for the Air Quality System (AQS). Table 5-4 summarizes the calculated percentile distribution of arithmetic mean concentrations of acetone across the United States using data from AQS from 2016 to 2020.

Table 5-4. Percentile Distribution of Annual Mean Acetone Concentrations (ppb Carbon) Measured in Ambient Air at Locations Across the United States

Year	Number of U.S. locations	Percentile				
		25th	50th	75th	95th	Maximum
2016	170	3.41	7.62	12.3	21.3	44.7
2017	165	3.45	8.33	12.4	19.8	156
2018	166	3.94	8.14	12.4	19.4	116
2019	124	3.29	8.38	12.4	18.6	57.9
2020[a]	87	3.15	7.12	11.9	18.5	52.0

[a] Data current as of November 2020.

Source: EPA 2020

Levels of acetone in urban, rural, and remote areas in the United States and the level in the troposphere are shown in Table 5-5. Table 5-5 indicates that concentrations of acetone in air are variable and tend to be higher in urban rather than rural settings. Besides these data, air monitoring data from an urban area (Tulsa, Oklahoma), a rural area (Rio Blanco County, Colorado), and a remote area (Smoky Mountain, Tennessee) are also available (Arnts and Meeks 1981). These data are not presented in Table 5-5 because the samples were collected in Tedlar bags that are known to contaminate air samples with acetone. Tables 5-5 and 5-6 also indicate that the indoor concentration of acetone is generally higher than the outdoor concentration. Other investigators reported similar results (Jarke et al. 1981). The reason for the higher indoor air concentration is the use of acetone-containing consumer products inside homes. Herberger et al. (2010) reports that the average indoor air concentration of acetone is 570 $\mu g/m^3$, with possible sources including expired air.

Acetone in water volatilizes fairly rapidly; thus, there is potential for inhalation exposure during showering and bathing. ATSDR's three-compartment Shower and Household Water-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 TWA exposure concentration via inhalation exposure and from dermal uptake from skin contact. For example, using a tapwater concentration of 0.5 ppm, the SHOWER model v2.0 predicts a daily continuous-exposure concentration of 0.05 ppm for a four-person household. This concentration is well below ATSDR's acute, inhalation MRL of 8 ppm. ATSDR's

Table 5-5. Outdoor Air Monitoring Data for Acetone

Location(s)	Geographic type	Date(s)	Range (ppb)	Mean concentration (ppb)	Notes	Reference
United States		5/18/2004–7/14/2004	80–4,700	814.8	25 samples; 10 detections.	WQP 2021
Canada	All	2000–2009	0.003–14.8	No data	Measured 3,688 samples over 24-hour sampling periods; median of 1.2 ppb and 95th percentile of 2.8 ppb.	Environment Canada 2014
Canada	Rural	2000–2009	0.03–9.4	No data	Measured 285 samples over 24-hour sampling periods; median of 1.2 ppb and 95th percentile of 2.8 ppb.	Environment Canada 2014
Canada	Commercial	2000–2009	0.01–5.8	No data	Measured 460 samples over 24-hour sampling periods; median of 1.3 ppb and 95th percentile of 2.5 ppb.	Environment Canada 2014
Canada	Industrial	2000–2009	0.02–6.0	No data	Measured 3688 samples over 24-hour sampling periods; median of 1.2 ppb and 95th percentile of 3.8 ppb.	Environment Canada 2014
Greece, Cyprus, the Netherlands, Hungary, Belgium, Italy, Ireland, Finland, and Denmark	Urban	2004–2008	0.1–5.4	0.1	Measured 66 samples from 11 different cities; median of 2.6 ppb	Geiss et al. 2011
New York		1997–2003	No data	No data	Measured 114 samples for 2-hour periods; 6.1% of samples were non-detectable; median of 2.7 ppb; 25th, 75th, and 90th percentiles of 1.4, 5.9, and 18.5 ppb, respectively	NYSDOH 2005
Caribbean Sea		1988	0.18 – 0.95	0.38	Sea-level sampling	Zhou and Mopper 1993
Portland, Oregon	Urban	1987–1988		7.4	Sampling of air outside of newly constructed office buildings	Hodgson et al. 1991
Houston, Texas	Urban, industrial	1987–1988	No data	6.1	Measured 60 samples during 24-hour sampling intervals	Lagrone 1991
Ontario	Rural	1988	No data	1.7		Shepson et al. 1991

Table 5-5. Outdoor Air Monitoring Data for Acetone

Location(s)	Geographic type	Date(s)	Range (ppb)	Mean concentration (ppb)	Notes	Reference
United States		1975–1986	Lower quartile of 0.0 and upper quartile of 2.8	6.9	Measured 17 sample; median of 0.9 ppb	Shah and Singh 1988
Germany		1984–1985	No data	0.47	Ground-level sampling	Arnold et al. 1986
Germany		1984–1985	No data	0.12	Upper troposphere and lower stratosphere; altitudes of 5,900–11,300 m	Arnold et al. 1986
Tucson, Arizona	Urban	1982	No data	12.0	Measured 17 samples; standard deviation = 4.0 ppb	Snider and Dawson 1985
Santa Rita and Mt. Lemmon, Arizona	Rural	1982	No data	2.8	Measured 18 samples; standard deviation = 0.8 ppb	Snider and Dawson 1985
Troposphere (lower)		No data	No data	0.7		Dilling et al. 1984
Point Barrow, Alaska	Arctic conditions	1967	No data	1.1	Measured 25 samples over a 24-hour period	Cavanagh et al. 1969

WQP = Water Quality Portal

Table 5-6. Indoor Air Monitoring Data for Acetone

Location(s)	Geographic type	Date(s)	Mean concentration (ppb)	Notes	Reference
New Jersey	Suburban and rural	2003–2006	36.1	Measured 100 homes, 94 of which had detectable levels of acetone; median of 14.3 ppb; range of <5.0–1,201.1 ppb	Weisel et al. 2008
Ottawa, Canada	Urban and suburban	2002–2003	18.4	Measured 75 homes with 99% detection frequency; median of 11.8 ppb; range of 0.006 to 188.8 ppb; 75th and 90th percentiles of 19.4 and 31.6 ppb, respectively	Zhu et al. 2005
New York	Not specified, homes were mostly near the Albany area	1997–2003	Not reported	227 samples of fuel oil heated homes. Median of 8.7 ppb; 25th, 75th, and 90th percentiles were 4.1, 21.5, and 45.6 ppb, respectively	NYSDOH 2005
United States	Not specified. Sampling of 56 office buildings	1995–1998	Not reported	Range of 7.1–220 ppb' median of 29 ppb; 168 samples (3 per building) collected over summer or winter months	Girman et al. 1999
New Jersey and Pennsylvania	Non-tobacco smoking homes	1992	20.8	Sampled 60 home; range of 1.2–161.4 ppb; median of 14.0 ppb; SD of 24.2 ppb	Heavner et al. 1996
New Jersey and Pennsylvania	Tobacco smoking homes	1992	29.5	Sampled 29 homes; range of 8.2–275.4 ppb; median of 16.3 ppb; SD of 48.9 ppb	Heavner et al. 1996
New Jersey and Pennsylvania	Non-tobacco smoking workplaces	1992	24.7	Sampled 52 workplaces; range of 2.3–171.6 ppb; median of 11.8 ppb; SD of 33.0 ppb.	Heavner et al. 1996
New Jersey and Pennsylvania	Tobacco smoking workplaces	1992	394.7	Sampled 28 workplaces; range of 3.4– 8732.3 ppb; median of 25.1 ppb; SD of 1,651.8 ppb	Heavner et al. 1996
Portland, Oregon	Urban	1987–1988	12.1–28.1	Samples from newly constructed office buildings collected August and October 1987 and January and October 1988	Hodgson et al. 1991
California and New Jersey	Residential and occupational sites	1981–1984	8.0	Measured 4 samples; median of 8.57 ppb; lower quartile of 4.5 ppb and upper quartile of 11.4 ppb	Shah and Singh 1988

SD = standard deviation

SHOWER model is available by sending a request to showermodel@cdc.gov. Vapor intrusion may also be a potential source of acetone exposure, as vapor intrusion has been observed for several VOCs with similar properties (Burk and Zarus 2013). Indoor air measurements in a review of 16 vapor intrusion sites (Table 5-7) fell within the range of those found at sites with no known hazardous waste (Table 5-6). However, only 2 of the 16 vapor intrusion sites had sufficient data (indoor air, outdoor air, and soil gas) to fully evaluate the vapor intrusion pathway. EPA's compilation of six studies of background indoor air concentrations found a 94–99% detection rate for acetone in 937 U.S. resident samples between 1996 and 2006 (EPA 2011). The background medians ranged from 21 to 49 $\mu g/m^3$, 95th percentiles ranged from 140 to 190 $\mu g/m^3$, and maximum values ranged from 257 to 2,900 $\mu g/m^3$. The potential for intrusion of acetone present as soil gas into a house adjacent to a landfill by diffusive and advective routes was found to be low (Hodgson et al. 1992). However, only a single house was studied. Two separate measurements were made, and basement air concentrations were found to be 12 and 82 ppb (v/v). Table 5-7 lists maximum measured values of acetone in various environmental media in U.S. hazardous waste sites.

5.5.2 Water

Data for water monitoring and drinking water monitoring for acetone are summarized in Tables 5-8 and 5-9, respectively. In 50,125 groundwater samples collected in the United States for the Water Quality Portal (WQP) between 2000 and 2021, 13,903 contained detectable levels of acetone ranging from 0 to 42,000 µg/L with an average concentration of 55.6 µg/L (WQP 2021). Several U.S. Geological Survey (USGS) studies have detected acetone in groundwater. A study of 54 wells in Clinton County, Pennsylvania in 2017 found acetone in 1 of 54 samples at a maximum concentration of 45.9 µg/L, and the concentration did not exceed the EPA drinking-water standards (USGS 2020). A study of 12 carbonate aquifers across the United States from 1993 to 2005 found that acetone was one of the most frequently detected volatile organic compounds and was most often found in urban and mixed land-use locations (USGS 2009). The maximum concentration was 6.97 µg/L (USGS 2009). The National Water Quality Assessment Program conducted sampling of acetone in groundwater and finished water in 24 community water systems in the United States and found non-detectable levels of acetone (<6 or <7 µg/L) in the majority of samples (USGS 2007). The highest concentration observed was 68 ppb in an aquifer in Florida (USGS 2007). In 103 finished water samples collected for WQP between 2002 and 2009, 30 samples contained detectable levels of acetone ranging from 1.4 to 20.2 µg/L (WQP 2021). In a National Organics Reconnaissance Survey (NORS) by EPA involving drinking water supplies from 10 cities in the United States, acetone was qualitatively detected in all 10 water samples. The 10 cities in

Table 5-7. Maximum Measured Values of Acetone at Selected Hazardous Waste Sites with Potential for Vapor Intrusion

Site name	Location	Date	Environmental medium	Maximum measured value (ppb)	Reference
Laugh and Learn Daycare	Ashville, Ohio	6/18/07	Indoor air	10.0	ATSDR 2007a
			Soil gas	3.5	
			Outdoor air	6.3	
Krouts Creek HC	Huntington, West Virginia	6/14/07	Soil gas	140.3	ATSDR 2007b
Sal's Auto Repair	Neptune City, New Jersey	4/4/07	Soil gas	88.6	ATSDR 2007c
Gorham	Providence, Rhode Island	12/4/06	Soil gas	69.6	ATSDR 2006a
Chevron	Hooven, Ohio	11/27/06	Soil gas	5,110.5	ATSDR 2006b
Brewer Brothers	Cardwell, Missouri	9/30/06	Soil gas	29.5	ATSDR 2006c
Brookhaven Landfill	Brookhaven, New York	11/29/05	Outdoor air	50.6	ATSDR 2005a
McCook VOC Vapor Intrusion Site	McCook, Nebraska	9/7/05	Indoor air	13.9	ATSDR 2005b
Bagley Bank	Bagley, Minnesota	7/13/05	Indoor air	16.3	ATSDR 2005c
Bachman Spill Site	Washington Township, Pennsylvania	6/21/05	Indoor air	51.1	ATSDR 2005d
Silver Creek Subdivision	Tucson, Arizona	6/3/05	Indoor air	0.2	ATSDR 2005e
Pemaco Superfund Site (VI Eval)	Maywood, California	4/29/05	Indoor air	160.3	ATSDR 2005f
			Soil gas	1,302.6	
			Outdoor air	674.9	
Matchbox Daycare	Warsaw, Indiana	3/15/05	Indoor air	26.5	ATSDR 2005g
Cooper's Poynt Elementary	Camden, New Jersey	2/9/05	Indoor air	12.2	ATSDR 2005h
			Outdoor air	5.1	
Sunoco	Greensburg, Pennsylvania	10/18/04	Indoor air	13.9	ATSDR 2004a
Freeland Garland Trichloroethylene Site	Freeland, Pennsylvania	8/9/04	Indoor air	21.0	ATSDR 2004b
			Outdoor air	10.0	
		6/26/03	Indoor air	42.1	ATSDR 2003

this survey were Cincinnati, Ohio; Miami, Florida; Ottumwa, Indiana; Philadelphia, Pennsylvania; Seattle, Washington; Grand Forks, North Dakota; Lawrence, Kansas; New York, New York; Terrebonne Parrish, Louisiana; and Tucson, Arizona (Bedding et al. 1982; Coleman et al. 1976; Keith et al. 1976). The determined concentration of acetone in one of the drinking water samples (Seattle, Washington) was 1 ppb (Keith et al. 1976). Acetone has also been detected in water from several artesian wells adjacent to a landfill in Wilmington, Delaware at a concentration of 0.3 ppb in finished drinking water from one of the wells (DeWalle and Chian 1981). The concentration of acetone was 3,000 ppb in a contaminated drinking water well in New Jersey (Burmaster 1982; Steelman and Ecker 1984).

Acetone was detected in 1,238 of 3,970 surface water samples in the United States collected for WQP between 2000 and 2021 at concentrations ranging from 0 to 25,000 µg/L (0–25,000 ppb) with an average concentration of 35.2 µg/L (35.2 ppb) (WQP 2021). Acetone has been detected at low levels (median of 2.6 ppb) in streams in New York and New Jersey (USGS 1997). Higher concentrations (>100 ppb) have been reported in several samples of storm water runoff from industrial sites (Line et al. 1997). The concentration of acetone in open ocean water (Tongue of the Ocean, Bahamas) was 6 nM (0.35 ppb) (Kieber and Mopper 1990), whereas the reported mean concentrations in seawater from the Straits of Florida and the Eastern Mediterranean were 20 and 30 ppb, respectively (Corwin 1969). The concentration of acetone in the Potomac River, Virginia was below the detection limit of 40 ppb (Hall et al. 1987).

Acetone in one sample of industrial effluent in the United States from 2009 reported in the WQP was below the detection level of 0.05 mg/L (WQP 2021). In 89 samples of leachate collected between 2002 and 2020 in the United States, 12 samples contained acetone at detectable levels ranging from 0.028 to 360 mg/L (WQP 2021). In five samples of wastewater treatment plant effluent in the United States from 2003 to 2007, acetone was detected in two samples, at concentrations of 0.041 and 0.044 mg/L, while the other three samples were below the detection limit of 0.0012 mg/L (WQP 2021). Acetone has been detected in the effluent from a textile plant (Gordon and Gordon 1981) and in effluent water from a specialty- chemicals manufacturing plant at a concentration of 200–230 ppm (Jungclaus et al. 1978). The compound has also been detected in groundwater, leachate, and run-off waters from landfill sites (Brown and Donnelly 1988; Connecticut Agricultural Experiment Station 1986; DeWalle and Chian 1981; Gould et al. 1983; Stonebraker and Smith 1980). The concentration of acetone in an industrial landfill leachate in Michigan was in the range of 0.05–62.0 ppm (Brown and Donnelly 1988). However, the quality of the reported data is uncertain. Acetone was detected at a mean concentration of 56 ppb in a landfill leachate in Orange County, Florida (Hallbourg et al. 1992).

Table 5-8. Water Monitoring Data for Acetone

Location(s)	Geographic type	Date(s)	Range (pbb)	Mean concentration (pbb)	Notes	Reference
New York and New Jersey	Streams	1997	Not reported	Not reported	Detectable levels in 64% of samples; detection limit of 5 ppb; median concentration of 2.6 ppb and maximum concentration of 6.6 ppb	USGS 1997
North Carolina	Industrial	1993–1994	Not reported	Not reported	Storm water runoff from industrial sites. Acetone not detectable (less than the minimum detection limit of 100 ppb) in seven of nine first-flush samples; detectable levels (>100 ppb) in two samples	Line et al. 1997
Tongue of the Ocean, Bahamas	Open ocean	Not reported	Not reported	0.35	Sampling depth: 200 m	Kieber and Mopper 1990
Potomac River, Virginia	River surface water	1986	Not reported	<40	Composite samples collected from three field stations	Hall et al. 1987
Straits of Florida	Sea water	February 1968	14–52	23.3	11 total samples (1 non-detect, <5 ppb); collected at depths of 0–518 m	Corwin 1969
Eastern Mediterranean	Sea water	August 1965	18–53	32.9	16 samples measured; collected at depths 0–1,200 m	Corwin 1969

Table 5-9. Drinking Water Monitoring Data for Acetone

Location(s)	Geographic type	Date(s)	Range (ppb)	Mean concentration (pbb)	Notes	Reference
United States	Groundwater (15 principal aquifers)	2002–2005	<6–68.36	<6 or 7	Majority of samples were too low to be quantified (<6 or <7 ppb), non-detects; however, Florida aquifer system (unconfined unit) contained 68.36 ppb	USGS 2007
New Jersey	Drinking water well	1980		3,000		Burmaster 1982; Steelman and Ecker 1984
Wilmington, Delaware	Drinking water wells	Mid-1977	0.2–0.7	0.35	Six samples from wells (including finished water); wells located adjacent to a landfill	DeWalle and Chian 1981
Seattle, Washington	Finished drinking water	1975	Not reported	1 ppb		Keith et al. 1976

5.5.3 Sediment and Soil

There are few data regarding the level of acetone in soil and sediment. In 811 samples of soil collected between 2000 to 2015 in the United States, acetone was detected in 245 at concentrations ranging from 1 to 5,300 µg/kg and averaging 141.8 µg/kg (WQP 2021). The maximum concentration of acetone in soils from Vega Alta Public Supply well sites in Puerto Rico was 9,500 ppb (ATSDR 1988). The mean concentration of acetone in soil from Summit National Site, Ohio, was 9,484 ppb (dry weight) (EPA 1988b). In 3,265 samples of sediment in the United States from 2000 to 2020, acetone was detected in 2,134 samples with concentrations ranging from 2 to 8,820,000 µg/kg and averaging 6,785 µg/kg (WQP 2021). Acetone has been qualitatively detected in river sediment that received effluents from a specialty chemicals manufacturing plant (Hites and Lopez-Avila 1980). A concentration of 6 ppb acetone was detected in the sediment of a creek adjacent to a landfill in Louisville, Kentucky (Stonebraker and Smith 1980). Because of its high water solubility and low sediment adsorption coefficient, most acetone in an aquatic system will be found in water, rather than in sediment.

5.5.4 Other Media

Acetone has been qualitatively detected as a volatile component of a number of foods including blue cheese (Day and Anderson 1965), baked potatoes (Coleman et al. 1981), roasted filbert nuts (Kinlin et al. 1972), meat (Grey and Shrimpton 1967; Shahidi et al. 1986), and nectarines (Takeoka et al. 1988). In kiwi fruit, the acetone concentration comprised 0.2% of total volatile components (Bartley and Schwede 1989). The concentrations of acetone in dry legumes, such as beans (mean of several varieties), split peas, and lentils were 880, 530, and 230 ppb, respectively (Lovegren et al. 1979). The level of acetone in headspace volatiles of Bisbee Delicious apples ranged from 111 to 912 pL/kg-hour (Mattheis et al. 1991). The percent of acetone (of the total) in commercial concentrated aqueous orange essences ranged from 0.003 to 0.009% (Moshonas and Shaw 1990).

Acetone is also found naturally in dairy milk and breastmilk, as it is produced endogenously in both cows and humans. In a study carried out in Czechoslovakia, the concentrations of acetone in samples of milk and cream culture were 0.8 and 0.001 ppm, respectively (Palo and Ilkova 1970). Acetone also has been qualitatively detected in breast milk of working mothers, although the study did not identify whether the concentrations of acetone were higher than normal physiologic levels (Giroux et al. 1992). Acetone has been qualitatively detected in 8 of 12 mothers’ milk samples collected from two locations in New Jersey; Bridgeville, Pennsylvania; and Baton Rouge, Louisiana (Pellizzari et al. 1982). More recent studies of volatile organic compounds in human breastmilk did not measure acetone concentrations (Blount et al. 2010; Kim et al. 2007).

Acetone has been detected in occasional rain samples collected in Hanover, Germany (Levsen et al. 1990). The authors were not sure whether the detection of acetone in the rain water was due to contamination of samples during analysis. The concentration of combined acetone and acrolein was 0.05 ppm in a rain water sample from Los Angeles, California (Grosjean and Wright 1983). The investigators could not separate acetone from acrolein by the method used for the determination of carbonyl compounds.

5.6 GENERAL POPULATION EXPOSURE

Acetone is endogenously produced by all humans. The general population is exposed to acetone by inhaling ambient air, ingesting food, and drinking water containing acetone. A recent study reported acetone emissions from children's 3-D pens and 3-D printer toys, with a range of acetone air concentrations of 1.5−9.4 ppb (3.1−22.4 μg/m^3) (Yi et al. 2019). Dermal exposure to acetone may result from skin contact with certain consumer products (e.g., certain nail polish removers, paint removers, and household cleaning and waxing products) (see Section 5.2.3). However, no quantitative data for dermal exposure to acetone from consumer products were located. Inhalation and daily intake rates for the general population can be estimated using monitoring data (see Section 5.5.1 and 5.5.2). Considering a high exposure scenario, the concentration of acetone is 36.1 ppb (85.75 μg/m^3) in indoor air (Weisel et al. 2008), and 6.9 ppb (16.38 μg/m^3) in outdoor air. Then assuming that a person inhales 15 m^3/day of indoor air and 5 m^3/day of outdoor air, the estimated inhalation rate of acetone is 1.64 mg/day. No experimental or estimated data were located regarding the daily intake of acetone in the general population in the United States from ingestion of drinking water and food. However, the daily intake for acetone (assuming a person consumes 2 L of drinking water/day) from this source would be <approximately 0.012 mg/day based on the assumption that the level of acetone in drinking water is <6 ppb (Section 5.5.2).

The acetone concentrations in body fluids and expired air of healthy and diabetic individuals are given in Table 5-10. The concentration of acetone in whole blood does not differ from that in plasma (Gavino et al. 1986). Even in healthy subjects, the level of acetone in blood/plasma varies with fasting or nonfasting conditions and depends on the weight of the subject. Generally, the blood/plasma acetone concentrations are higher in fasted than nonfasted subjects and higher in subjects who are not obese, compared to obese subjects (Haff and Reichard 1977). An analysis of data from the Third National Health and Nutrition Examination Survey (NHANES III) found that the mean concentration of acetone in whole blood was 3.1 mg/L (Ashley et al. 1994). Blood acetone concentrations varied widely: the 5th percentile was 0.64 mg/L and the 95th percentile was 6.0 mg/L.

Table 5-10. Concentrations of Acetone in Human Biomarkers Collected in the United States

Medium	Concentration	Subjects	Reference
Whole blood	3.1 mg/L	NHANES III sample	Ashley et al. 1994
Whole blood	0.84 mg/L	Healthy	Wang et al. 1994
Whole blood	1.26 mg/L	Healthy	Jones et al. 1993
Whole blood	1.90 mg/L	Diabetic	Jones et al. 1993
Whole blood	2.03 mg/L	Drunk drivers	Jones et al. 1993
Whole blood	0.93 mg/L	Healthy (nonfasted)	Gavino et al. 1986
Plasma	46.5 mg/L	Healthy (fasted)	Haff and Reichard 1977
Plasma	1.74 mg/L	Healthy (nonfasted)	Trotter et al. 1971
Plasma	290 mg/L	Ketoacidotic	Haff and Reichard 1977
Plasma	424 mg/L	Ketoacidotic	Trotter et al. 1971
Urine	0.84 mg/L	Healthy	Wang et al. 1994
Urine	0.76 mg/L	Healthy	Pezzagno et al. 1986
Urine	0.23–0.41 mg/L	Healthy	Kobayashi et al. 1983
Urine	0.64–9.0 mg/L	Diabetic	Kobayashi et al. 1983
Expired air	1.3 µg/L	Healthy	Phillips and Greenberg 1987
Expired air	0.1 µg/L	Healthy	Krotoszynski et al. 1979
Expired air	1.16 µg/L	Healthy	Trotter et al. 1971
Expired air	1.23 µg/L	Healthy	Jansson and Larsson 1969

NHANES = National Health and Nutrition Examination Survey

5.7 OPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers in industries that manufacture or use acetone are one segment of the population at an especially high risk of acetone exposure compared to the general population (see Section 5.6). Professional painters, salon workers, factory workers, and commercial and household cleaners (who use certain detergents, cleansers, waxes, or polishes that contain acetone) are also likely to be exposed to acetone at higher concentrations than the general population. In a small printing factory in the United States, employees were exposed to short-term average concentrations of acetone ranging from 11.4 to 41.4 ppm during printing and cleaning activities, respectively (Lee et al. 2009). The concentration of acetone in the breathing zone air of a solvent recycling plant in the United States ranged from not detected to 43 mg/m^3 (Kupferschmid and Perkin 1986). Several studies of workplaces in foreign countries have measured acetone concentrations in breathing zone air. The concentrations of acetone in the breathing zone air in a paint factory, a plastics factory, and an artificial fiber factory in Italy were >3.48 mg/m^3 (Pezzagno et al. 1986). The concentration of acetone in the breathing zone air of a fiber-reinforced plastic plant in Japan, where bathtubs were produced, was <108 mg/m^3 (Kawai et al. 1990a). The inhalation exposure for workers to acetone in a shoe factory in Finland ranged from 25.4 to 393.4 mg/m^3 (Ahonen and Schimberg 1988). Concentrations of acetone in the breathing zone air in shoe factories in Italy were also high (Brugnone et al. 1978). High levels of acetone were also detected in the ambient air in other industries including chemical, plastic button, and paint manufacturing industries in Italy (Ghittori et al. 1987).

Several studies have measured indoor air concentrations of acetone in nail salons across the United States to analyze exposures of nail salon workers. One study found that salon workers are exposed to acetone while painting nails, and nail polish samples contained 0.56 to 8.07 ppm acetone (Heaton et al. 2019). In a study of salons in New York City, Philadelphia, and southern New Jersey, the mean personal chemical exposure ranged from 3.30 to 58.47 ppm across 25 salons; the total mean personal exposure for acetone was 18.51 ppm (Ma et al. 2019). The median personal exposure to acetone in 6 salons in Colorado ranged from 8.0 to 30 ppm, with an overall range of 3.6–45 ppm (Lamplugh et al. 2019). In 12 randomly selected nail salons in Salt Lake County, Utah, the concentration of acetone ranged from 1.6 to 13 ppm with a mean of 6.1 ppm (Alaves et al. 2013). The concentration of a control sample taken from a single family residence with no nail products was 0.011 ppm (Alaves et al. 2013). The range of acetone concentrations in 3 Alameda County, California air salons was 0.31 to 6.60 ppm, with a mean concentration of 3.10±3.20 ppm (Quach et al. 2011). NIOSH (2019a) found that the mean full-shift personal air concentrations of acetone in air across three salons was 9.06 ppm. The concentration ranged from 2.7 to 29 ppm (NIOSH 2019a). One study of nail salons in Norway found mean acetone concentrations of 3.50 ppm (range 0.05–16.4 ppm) in breathing zones of the 32 technicians sampled (Gjølstad et al. 2006). Exposure to acetone in nail salons can be limited by using dispensers that reduce spills, not leaving acetone in open bowls or containers, not heating acetone, and using gloves when handling acetone (NIOSH 2019a).

Among the general population, high exposure to acetone may occur among several subgroups. Cigarette smoke contains acetone, and a cigarette may generate 50 to 550 µg of acetone (Counts et al. 2005; HHS 2010; Polzin et al. 2007). In Juul electronic cigarettes, the mean concentration of acetone in aerosols was 0.20±0.05 µg/puff, with no significant differences among flavors (Reilly et al. 2019). People who smoke cigars (both filtered and little cigars) may be exposed to higher levels of acetone per cigar than those who smoke cigarettes (Reilly et al. 2018a). Using the International Organization of Standards method to detect acetone in smoke, acetone concentrations were: 11.8±0.1–18.0±1.1 µg/puff in cigarettes, 23.2±1.0–23.3±0.3 µg/puff in filtered cigars, and 32.9±4.3–41.2±5.0 µg/puff in little cigars (Reilly et al. 2018a, 2018b). While the concentrations measured using the Health Canada Intense machine-smoking protocols were higher, a similar distribution was observed between the types of product sampled (Reilly et al. 2018a, 2018b). Concentrations of acetone in workplaces with tobacco smoking have been found to be significantly higher than in workplaces with no tobacco smoking (Heavner et al. 1996). Therefore, people who smoke tobacco and individuals exposed to environmental tobacco smoke are exposed to higher concentrations of acetone than those in non-tobacco smoking environments. The content of acetone in certain nail polish removers is high; the concentration of acetone in one brand of remover used in Michigan nail salons was 413.5±4.4 g/m^3 (Zhong et al. 2019a, 2019b), and nail polish removers used in salons in the Greater Boston Area were all 100% acetone (Ceballos et al. 2019). Therefore, individuals who frequently use nail polish removers are exposed to higher levels of acetone than the general population. People who live near landfill sites that emit acetone or those who live near industrial sources of emission (e.g., refinery, incinerator, close to high vehicular traffic areas) are also susceptible to higher exposure concentrations of acetone than the general population that does not reside near these sites. People who consume contaminated well water (see Section 5.5.2) as drinking water are subject to higher exposures. People who consume food containing acetone excessively would also be subject to high exposure, especially if associated with other risks. Those who choose a ketogenic diet or take ketone supplements may be at increased risk of exposure to greater levels of ketones than are endogenously produced, though limited literature outlines the long-term effects of ketogenic diets (Masood et al. 2020).