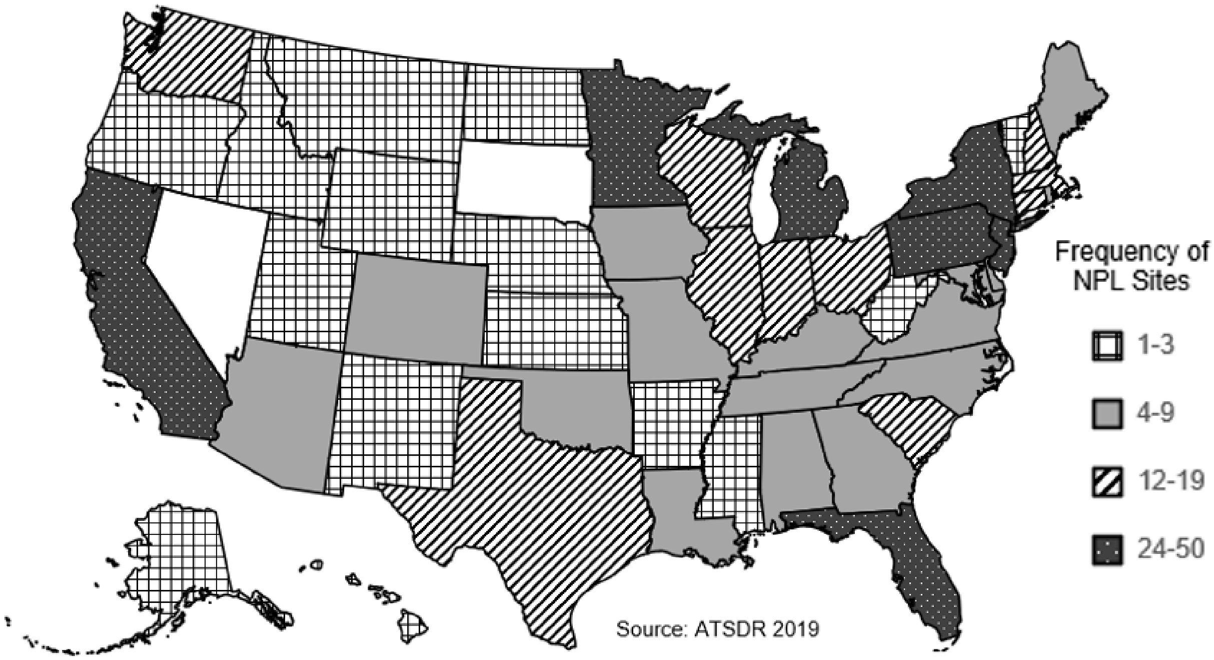
CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

2-Butanone has been identified in at least 526 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 2-butanone has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, 523 are located within the United States and 3 are located in Puerto Rico (not shown).

Figure 5-1. Number of NPL Sites with 2-Butanone Contamination



Source: ATSDR 2019

- The most likely routes of 2-butanone exposure for the general public include ingestion of food, ingestion of contaminated drinking water, inhalation during household use of coating products, and dermal contact during the use of these products. High levels of occupational exposure to 2-butanone may occur by inhalation and dermal contact during the loading and unloading of large quantities of commercial coating materials during shipment. The application of commercial coatings containing 2-butanone without adequate protection may also lead to high levels of exposure, primarily by inhalation.

- 2-Butanone is detected in environmental media, although usually at low levels. 2-Butanone is expected to rapidly volatilize from surface water and moist or dry soils and exists as a vapor in the atmosphere. 2-Butanone displays a high mobility in soil and leaches readily into groundwater. 2-Butanone does not adsorb strongly to soils and sediments or bioconcentrate in aquatic organisms.

- 2-Butanone undergoes degradation in the atmosphere although the mechanisms responsible for this process are not known. Biodegradation is expected to occur in soil and water under both aerobic and anaerobic conditions.

2-Butanone may be released to the atmosphere in fugitive emissions during its production, transport, and use. In urban areas, it can exist in the atmosphere as a result of automobile exhaust, the decomposition of other organic compounds, and from natural sources.

The release of 2-butanone to water or soil is not well documented. Release of 2-butanone to surface water may occur via industrial wastewater emissions. 2-Butanone may also be released to soil or water from a spill or other catastrophic event. The leachate of landfills and hazardous waste sites may result in 2-butanone contamination of soil and groundwater.

2-Butanone is expected to rapidly volatilize from surface water and moist or dry soils to the atmosphere. In the atmosphere, this compound is expected to exist predominantly in the vapor phase. Wet deposition may return 2-butanone to the earth’s surface.

In soil, 2-butanone is expected to display very high mobility, and it has the potential to leach into groundwater. This characteristic also suggests that it does not significantly adsorb to sediment and suspended organic matter in surface waters. 2-Butanone is not expected to bioconcentrate in fish or aquatic organisms.

Although the degradation of 2-butanone in the environment is understood on a theoretical level, data are not available to quantify all conclusions. In the atmosphere, 2-butanone is expected to undergo a vapor-phase reaction with photochemically produced hydroxyl radicals; the half-life for this process is approximately 1 day. However, laboratory experiments have suggested that the atmospheric half-life of 2-butanone is much shorter.

In water, 2-butanone is expected to undergo microbial degradation under both aerobic and anaerobic conditions. Chemical oxidation, direct photolysis, and hydrolysis of 2-butanone under environmental conditions are not expected to occur to any significant extent. Data on the fate of 2-butanone in soil are not available.

Various data are available regarding the concentration of 2-butanone in environmental media. It has been qualitatively detected in U.S. drinking water supplies and as a naturally occurring constituent of foods. It has also been detected in the air.

The general population is exposed to 2-butanone by drinking contaminated water or by the ingestion of food containing it. Members of the general population living near hazardous waste sites may be exposed to contaminated drinking water if their household water source is well water. The general population is also expected to be exposed to 2-butanone by inhalation, especially in urban areas. The use of commercial coatings containing 2-butanone also results in exposure by inhalation, and possibly by dermal contact as well. High levels of exposure may occur for members of the general population if these coatings are used in an enclosed, unventilated area. Occupational exposure to 2-butanone may occur by inhalation during the production, formulation, use, or transport of this compound.

5.2 PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.2.1 Production

No information is available in the TRI database on facilities that manufacture or process 2-butanone 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).

According to the most recent edition of U.S. Chemical Data Reporting on chemical production and use in the United States (EPA 2020), the National Aggregate Production Volume of 2-butanone in 2015 was 100,000,000–250,000,000 pounds. The National Aggregate Production Volumes of 2-butanone were 282,480,991, 100,000,000–250,000,000, 100,000,000–250,000,000, and 50,000,000–100,000,000 pounds in 2011, 2012, 2013, and 2014, respectively. U.S. facilities that produced, processed, or used 2-butanone in 2015 are included in Table 5-1.

Table 5-1. Facilities that Produce, Process, or Use 2-Butanone

State	Number of facilities
Alabama	1
Arkansas	1
California	2
Delaware	1
Florida	3
Illinois	2
Indiana	2
Kentucky	2
Louisiana	1
Massachusetts	1
Minnesota	1
Missouri	1
New Jersey	8
New York	2
Ohio	6
Oregon	2
Pennsylvania	2
South Carolina	1
Texas	9
Washington	1
Wisconsin	3

Source: EPA 2020

2-Butanone is produced on a commercial scale by one of two processes. The catalytic dehydrogenation of 2-butanol in the gas-phase accounts for 92% of 2-butanone production (2006). The remaining 8% of 2-butanone is produced by a process in which liquid n-butane is oxidized catalytically to produce acetic acid and 2-butanone as a byproduct (Hoell et al. 2012).

5.2.2 Import/Export

No publicly accessible data were located to indicate the amount of 2-butanone exported or imported from or to the United States.

5.2.3 Use

2-Butanone is an important solvent with properties similar to those of acetone. 2-Butanone exhibits a very high power of dissolution. Some natural substances, plastics, and resins can be dissolved in 2-butanone. Areas of application are production of paints, lacquers, varnishes, paint thinners and removers, adhesives, cements, sealants, magnetic tapes, artificial leather, transparent paper, printing inks, cleaner for electronic equipment, cosmetics, pharmaceuticals; degreasing of metal surfaces; extraction of fats, oils, waxes, natural resins; and dewaxing of mineral oils or lube oils. Additionally, it is used as a synthetic flavoring agent in foods and pharmaceuticals and as a sterilizer for bacterial spores on surgical instruments, hypodermic needles and syringes, and dental instruments. It is also used in the manufacturing of smokeless powders (Hoell et al. 2012), which are ammunition propellants.

5.2.4 Disposal

Incineration can be used to dispose of 2-butanone by spraying into incinerators or burning in paper packaging (NLM 2020). 2-Butanone has been reported to be amenable to biological degradation in sewage treatment plants (Babeu and Vaishnav 1987; Bridie et al. 1979; Gaudy et al. 1963; Price et al. 1974; Urano and Kato 1986; Vaishnav et al. 1987; Young et al. 1968). No data are available regarding the amount disposed by each of these methods, nor is any information available regarding the trends in the disposal of 2-butanone.

5.3 RELEASES TO THE ENVIRONMENT

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

There is no information on releases of 2-butanone to the atmosphere from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005).

2-Butanone may be emitted to the atmosphere during its production, formulation, storage, or use in commercial products. 2-Butanone may also be released to the atmosphere as a result of its use as a solvent in commercial products. It was identified as an emission from a variety of indoor building materials: latex caulk, particle board, latex paint, and polyurethane floor finish (EPA 1987a; Tichenor and Mason 1988). Since 2-butanone is prevalent in adhesives and coatings (Papa and Sherman 1981), it may be released to the atmosphere during the curing of these products.

2-Butanone is present in the exhaust of automobiles (Seizinger and Dimitriades 1972). In a Swedish study, 2-butanone was detected in automobile exhaust, although the ambient air levels measured in Stockholm did not correlate with these emissions (Jonsson et al. 1985). Thus, the prevalence of other sources is indicated, as the air levels of 2-butanone were higher than could be explained solely by automobile emissions. Other potential sources of 2-butanone in the atmosphere include the burning of polyethylene (Hodgkin et al. 1982) and the photochemical degradation of hydrocarbons (Grosjean 1982), especially those emitted from motor vehicles. 2-Butanone was reported in the emissions of common household wastes (Wilkins and Larsen 1995, 1996) and in aerobic composting at a rate of 22 g/ton of waste, 0.8 g/ton in phase I of combined anaerobic/aerobic composting processes, and 0.1 g/ton in phase II (Smet et al. 1999). 2-Butanone is also emitted to the atmosphere from such natural sources as European firs, junipers, cedars, cypress trees, and ferns (Isidorov et al. 1985) and ant secretions (Cammaerts et al. 1978).

5.3.2 Water

There is no information on releases of 2-butanone to water from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005).

Limited data are available regarding the release of 2-butanone to surface and groundwaters. It has been detected in wastewater effluents from commercial processes (Dunovant et al. 1986; Hawthorne and Sievers 1984; Jungclaus et al. 1978; Pellizzari et al. 1979). 2-Butanone may also be present in water from the microbial oxidation of butane (Phillips and Perry 1974). Its relatively high water solubility, 136,000 mg/L at 25°C (Tewari et al. 1982), suggests that wet deposition of atmospheric 2-butanone results in the contamination of surface water. Evidence for this comes from the fact that 2-butanone has been detected in rainwater (Grosjean and Wright 1983).

The contamination of groundwater with 2-butanone has occurred at hazardous waste sites (Francis et al. 1980; Sawhney and Kozloski 1984) and landfills (Sabel and Clark 1984) due to infiltration of contaminated leachate. 2-Butanone is also likely to enter groundwater as a result of a spill to soil during a catastrophic event, such as a tanker spill (Halvorsen and Ohneck 1985).

2-Butanone may also enter water from natural sources. It has been detected in various species of macroalgae at concentrations as high as 2,600 ng/g (Whelan et al. 1982).

5.3.3 Soil

There is no information on releases of 2-butanone to soil from manufacturing and processing facilities because these releases are not required to be reported (EPA 2005).

Limited data are available regarding the release of 2-butanone to soil. The presence of this compound in the groundwater at hazardous waste sites and landfills (Francis et al. 1980; Sabel and Clark 1984; Sawhney and Kozloski 1984) suggests that leachate at these facilities will be a source of 2-butanone release to soil. Wet deposition of atmospheric 2-butanone may also result in its contamination of soil. 2-Butanone may enter soil during a catastrophic event, such as a tanker spill (Halvorsen and Ohneck 1985).

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

Air. In the atmosphere, 2-butanone is expected to exist predominantly in the vapor phase (Eisenreich et al. 1981; Riddick et al. 1986). This is consistent with experimental data, which demonstrated that the gas-phase concentration of 2-butanone in Los Angeles, California was 220–3,000 times greater than the particulate phase concentration (Grosjean 1982). The relatively high water solubility of 2-butanone, 136,000 mg/L at 25°C (Tewari et al. 1982), suggests that wet deposition may remove 2-butanone from the atmosphere. 2-Butanone has been identified in rainwater (Grosjean and Wright 1983). The absence of significant amounts of particulate 2-butanone indicates that dry deposition to the earth's surface is not an important fate process. The short residence time expected for 2-butanone in the atmosphere, <1 day, suggests that it is not transported long distances from its original point of release.

Water. If 2-butanone is released to water, it is expected to rapidly volatilize to the atmosphere. Based on its Henry's law constant, an estimated volatilization half-life from a model river 1 m deep, flowing at 1 m/second with a wind velocity of 3 m/second, is approximately 15 hours (Lyman et al. 1982).

Sediment and Soil. Based on an experimental soil adsorption coefficient (K_{oc}) of 3.55 (Roy and Griffin 1985), 2-butanone is expected to display very high mobility in soil (Swann et al. 1983). 2-Butanone was found in groundwater samples shortly after a tanker spill (Halvorsen and Ohneck 1985) and in the groundwater underneath hazardous waste sites and public landfills (Francis et al. 1980; Sabel and Clark 1984; Sawhney and Kozloski 1984). The vapor pressure of 2-butanone, 90.6 mmHg at 25°C (Riddick et al. 1986), and the Henry's law constant, 5.77×10^{-5} atm m^3/mol at 25°C, suggest that volatilization from either dry or moist soil to the atmosphere will be an important environmental process.

2-Butanone is not expected to significantly adsorb to sediment and suspended organic matter. It is also not expected to bioconcentrate in fish and aquatic organisms (Lyman et al. 1982). These conclusions are based on an experimental K_{oc} of 3.55 (Roy and Griffin 1985) and a calculated bioconcentration factor of 0.98 obtained from its octanol/water partition coefficient, 0.29 (Hansch et al. 1995), and an appropriate regression equation (Lyman et al. 1982).

5.4.2 Transformation and Degradation

Air. 2-Butanone is expected to undergo atmospheric destruction by the gas phase reaction with photochemically produced hydroxyl radicals. Rate constants for this reaction ranging from 1.85×10^{-11} to 9.8×10^{-13} atm/molecule-second in the temperature range of 22–32°C have appeared in the literature (Cox et al. 1980, 1981; EPA 1986; Edney et al. 1986; Darnall et al. 1976; Gusten et al. 1984; Wallington and Kurylo 1987; Wallington et al. 1988). Using a recommended rate constant of 1.85×10^{-11} atm/molecule-second at 25°C and an average atmospheric hydroxyl radical concentration of 5×10^5 molecule/cm^3 (Atkinson 1985), a half-life of 21 hours for this reaction can be calculated. However, experiments performed under simulated atmospheric conditions in the laboratory have shown that 2-butanone has a half-life of only 9.8 hours for photo-initiated processes (Dilling et al. 1976). The rate of its destruction increased in the presence of other anthropogenic compounds. The atmospheric destruction of 2-butanone as a result of direct irradiation is not expected to be significant under atmospheric conditions (Cox et al. 1980). Therefore, direct photolysis cannot account for the enhanced rate of atmospheric destruction observed in the laboratory. However, the data suggest that other mechanisms are responsible for the destruction of 2-butanone in the atmosphere, which are yet to be defined.

Water. 2-Butanone is expected to be removed from environmental waters by microbial degradation under both aerobic and anaerobic conditions. Limited data specific to the chemical degradation of 2-butanone in water are available; however, it is not expected to occur to any significant extent.

Numerous investigations have concluded that 2-butanone undergoes biological degradation under aerobic conditions. At an initial concentration of 1 ppm, 2-butanone completely degraded in aerated water obtained from a deep Florida aquifer within 14 days after a 5-day lag period (Delfino and Miles 1985). Screening studies using a microbial seed from domestic waste treatment plants have indicated that 2-butanone has a 5-day biological oxygen demand (BOD5), which is between 59 and 74% of the theoretical amount after a short lag period (Babeu and Vaishnav 1987; Bridie et al. 1979; Gaudy et al. 1963; Price et al. 1974; Urano and Kato 1986; Vaishnav et al. 1987; Young et al. 1968). A pure culture study indicated that propionate is produced as a result of the microbial oxidation of 2-butanone (Phillips and Perry 1974).

2-Butanone has been listed as a compound amenable to degradation by anaerobic biotechnology (Speece 1983). At an initial concentration of 500 ppm, 2-butanone was completely reduced to methane within 8 days in a fermenter using a domestic sludge inoculum that had been adapted to acetate (Chou et al. 1978).

An experimentally determined rate constant of 5.4×10^{8} L/mol-second has been determined for the reaction of 2-butanone with hydroxyl radicals in water (Anbar and Neta 1967). This value corresponds to a half-life of 4 years for this reaction, given a hydroxy radical concentration of 1×10^{-17} M (Mill et al. 1980). Hydrolysis of ketones is generally not believed to be an environmentally important process (Lyman et al. 1982; Mill 1982). A rate constant of 0 L/mol-year was listed for the hydrolysis of 2-butanone under neutral, acidic, and basic conditions at 25°C (EPA 1987b), indicating that this process does not occur in the environment. By analogy to the gas phase photolysis of 2-butanone (Cox et al. 1980), direct photochemical breakdown of 2-butanone in water is not expected. Therefore, the chemical degradation of 2-butanone in environmental waters is not expected to occur to any significant extent.

The chemical alteration of 2-butanone in rainwater has been postulated. In acid rain, hydroxy sulfonates may be formed by their action with bisulfite, and ammonia adducts may be formed in ammoniated rain (Grosjean and Wright 1983). The concentration of these reactive species is likely to be much higher in rainwater than in surface water; therefore, a more rapid rate of reaction would be expected in rain.

Sediment and Soil. No specific data concerning the fate of 2-butanone in soil were available. By analogy to the experimental results on the microbial degradation of 2-butanone in water, this compound may degrade in soil under aerobic and anaerobic conditions given suitable time for adaptation of the microbial population. Again by using an analogy to the fate of 2-butanone in aqueous systems, it is not expected to hydrolyze, photolyze on the surface, or undergo chemical degradation in soil.

5.5 LEVELS IN THE ENVIRONMENT

Reliable evaluation of the potential for human exposure to 2-butanone depends, in part, on the reliability of supporting analytical data from environmental samples and biological specimens. Concentrations of 2-butanone 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 2-butanone 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 5-2 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 5-3.

Table 5-2. Lowest Limit of Detection Based on Standards[a]

Media	Detection limit	Reference
Air	4 μg	NIOSH 1996
Air	8 ppb	Jonsson et al. 1985
Drinking water	No data	Wallace et al. 1984
Surface water and groundwater	10 ppb	EPA 1988
Soil	10 ppb	EPA 1988

Table 5-2. Lowest Limit of Detection Based on Standards[a]

Media	Detection limit	Reference
Sediment	10 ppb	EPA 1988
Whole blood	0.01 ppm	Van Doorn et al. 1989

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

Table 5-3. Summary of Environmental Levels of 2-Butanone

Media	Low	High	Mean
Outdoor air (ppb)	0.5	14	2.8
Indoor air (ppb)	No data	No data	No data
Surface water (ppb)	No data	No data	11
Groundwater (ppb)	No data	No data	302
Drinking water (ppb)	No data	No data	1.6
Soil (ppb)	No data	No data	87

Detections of 2-butanone in air, water, and soil at NPL sites are summarized in Table 5-4.

Table 5-4. 2-Butanone 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 (ppb)	200	401	26.9	158	94
Soil (ppb)	550	1,700	65.7	119	93
Air (ppbv)	15.9	16.8	21.4	33	20

[a]Concentrations found in ATSDR site documents from 1981 to 2019 for 1,867 NPL sites (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

2-Butanone has been detected in a limited number of sites in rural, urban, and indoor locations. It was detected in 17 samples taken in Tucson, Arizona, in 1982 at an average concentration of 2.8 ppb. In the mountains of Arizona, the concentration was 0.50 ppb (Snider and Dawson 1985). The range of 2-butanone measured in Los Angeles air in 1980 was 0–14 ppb in 70 samples (Grosjean 1982). An average concentration of 0.638 ppb of 2-butanone was obtained from 714 atmospheric samples in the United States (EPA 1988). The average concentration of 2-butanone at 25 urban locations in the United States was 1.4 $\mu g/m^3$ (0.48 ppb) (Kelly et al. 1993). 2-Butanone was found in one-third of samples taken downwind of a solvent recycling facility in Maryland in 1970, at a maximum concentration of 94 ppm (Smoyer et al. 1971). Although it has been detected in the exhaust of gasoline engines, 2-butanone was not found in the air of a highway mountain tunnel (Hampton et al. 1982).

2-Butanone was detected in the air of the Kin-But chemical waste site, located in New Jersey, at concentrations ranging from trace to 1.5 pg/m^3 (0.51 ppb); in samples surrounding the site, concentrations were 0.5–33 $\mu g/m^3$ (0.17–11.3 ppb) (Pellizzari 1982). It was qualitatively detected in the air at four of four hazardous waste sites and one landfill in New Jersey (LaRegina et al. 1986).

In a survey of 36 homes taken in Chicago, Illinois, 2-butanone was detected in the indoor air at 3 residences (Jarke et al. 1981). It was also found in three outdoor samples in this survey. It is not clear, however, if the positive indoor and outdoor samples were collected at the same location. In a compilation and analysis of ambient monitoring data collected from 1970 to 1987, the daily concentration of 2-butanone was 0 ppb in urban, suburban, and rural areas (EPA 1988). 2-Butanone has been qualitatively detected in the indoor air of homes in Chicago (Jarke et al. 1981) and in Canadian residential and office buildings (Tsuchiya 1987).

The sporadic ambient air monitoring data available for 2-butanone suggest that the average background concentration of this compound may be very low. However, the available data also suggest that there are dramatic, temporal, and diurnal variations in its concentration.

5.5.2 Water

From water quality data collected across the United States, 2-butanone was found at <2.0 µg/L (detection limit) in 1 of 107 samples of finished water (NWQMC 2020). 2-Butanone was identified as an ozone disinfection byproduct in drinking water (Richardson et al. 1999). 2-Butanone was detected in tap water 8 months after the installation of new polyvinyl chloride (PVC) pipes at a concentration ranging from 0.4 to 4.5 ppm (Wang and Bricker 1979). It resulted from the glue used to cement the water pipes together. The concentration of 2-butanone in the water increased with the amount of time the water sat in the pipes.

2-Butanone has been qualitatively detected in rainwater and the clouds of Henninger, California, at 0.04 ppb, and in the mist of Long Beach, California (Grosjean and Wright 1983). Trace amounts have also been found in the ice in Fairbanks, Alaska (Grosjean and Wright 1983).

Water quality data compiled from the STORET Data Warehouse and the U.S. Geological Survey (USGS) National Water Information System (NWIS) reports are summarized in Table 5-5. These data are comprised of water quality data from water resource management groups across the country.

Table 5-5. 2-Butanone Detected in Samples Collected Throughout the United States from 2010 to 2020

Type	Number of samples	Number of positive	Concentration range
Groundwater	21,395	3,072	0.09–5000 ppb
Surface water	1,093	66	0.3–<50 ppb
Storm water	9	9	<1.9–<50 ppb
Leachate	60	60	<50–2,450 ppb
Municipal waste	2	0	1.5 ppb (detection limit)
Sediment	37	0	0.89–4.30 ppb (detection limit)
Soil	18	0	1.1–330 ppb (detection limit)
Drinking water[a]	107	1	<2.0 ppb (detection limit)

[a] Samples taken 1998–2009; no results were reported for 2010–2020.

Source: NWQMC (2020).

2-Butanone has been detected in the effluent of various industrial processes. It was found in six of seven wastewater samples from energy-related processes at a concentration up to 645 ppb (Pellizzari et al. 1979). 2-Butanone was detected in the wastewater of a specialty chemical manufacturing plant at a concentration of 8–20 ppm, but not in the receiving river water or its sediment (Jungclaus et al. 1978). It was also detected in the wastewater from shale oil processing at a concentration of 0.4–18 ppm (Hawthorne and Sievers 1984). In 1982, 2-butanone was detected at concentrations of ≤83 ppb in the wastewater entering Cincinnati treatment plants (Dunovant et al. 1986).

2-Butanone was qualitatively detected in the Black Warrior River, located in Tuscaloosa, Alabama (Bertsch et al. 1975) and in Newark Bay, New Jersey (Gunster et al. 1993). It was also detected in seawater from the straits of Florida at 0–22 ppb in 1968 (Corwin 1969) and in the Potomac River at <40 μg/L (Hall et al. 1987).

5.5.3 Sediment and Soil

2-Butanone has been reported in soil samples collected from various mines and waste disposal facilities in the United States at concentrations ranging from 32 to 38,000 μg/kg (EPA 1987c, 1987d, 1988b, 1989).

5.5.4 Other Media

2-Butanone has been detected as a natural component of numerous types of foods. It has been qualitatively identified as a volatile constituent in raw chicken breast muscle, milk, roasted filberts (nuts), Beaufort (Gruyere) and cheddar cheese, bread dough, and intact tree-ripened nectarines (Dumont and Adda 1978; Gordon and Morgan 1972; Grey and Shrimpton 1967; Keen et al. 1974; Kinlin et al. 1972; Sosulski and Mahmoud 1979; Takeoka et al. 1988). The mean concentrations of 2-butanone in dried beans, split peas, and lentils were 148, 110, and 50 ppm, respectively (Lovegren et al. 1979). 2-Butanone has been detected in southern peas at a median concentration of 120 ppb (Fisher et al. 1979), and it has been qualitatively detected in winged beans and soybeans (Del Rosario et al. 1984). 2-Butanone is a constituent of plant families including Lamiaceae, Solanaceae, Myrtaceae, and Grossulariaceae (USDA 2020). It has also been detected in cigarette smoke (Higgins et al. 1983; Osborne et al. 1956).

5.6 GENERAL POPULATION EXPOSURE

Available monitoring data suggest that the general population is exposed to 2-butanone. In the early stages of the Total Exposure Assessment Methodology (TEAM) study, 2-butanone was qualitatively detected in 3 of 8 personal air samples, 5 of 12 breath samples, and 1 of 1 drinking water sample obtained from 12 volunteers living in urban areas of New Jersey or North Carolina (Wallace et al. 1984). 2-Butanone has also been detected in the expired air of 206 of 387 samples (53.2%) taken from 54 adult, nonsmoking, urban-dwelling subjects, at an average concentration of 3.6 ng/L (Krotoszynski et al. 1979). It was detected in the expired air of six of eight male volunteers, three of whom were smokers (Conkle et al. 1975). 2-Butanone was found in 5 of 12 samples of human mothers' milk from subjects in four different U.S. urban areas (Pellizzari et al. 1982). It has been qualitatively detected in the indoor air of homes in Chicago (Jarke et al. 1981) and in Canadian residential and office buildings (Tsuchiya 1987).

Exposure to 2-butanone by the general population may occur by ingestion of contaminated drinking water. This compound has been identified in U.S. drinking water supplies (Bertsch et al. 1975; Coleman et al. 1976; EPA 1974, 1975; Kopfler et al. 1977; Ogawa and Fritz 1985; Scheiman et al. 1974). However, in 107 finished water samples collected across the United States from 1990 to 2020, 2-butanone was detected in only one sample at <2 ppb (NWQMC 2020). Inhalation is also a likely route of exposure to 2-butanone, especially during the household use of commercial coatings that use 2-butanone as a solvent. Exposure by dermal contact may also occur during the use of such coatings.

2-Butanone in water is expected to rapidly volatilize; thus, there is potential for inhalation exposure during showering and bathing. 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. The SHOWER model predicts 40% volatilization of 2-butanone while showering and about 30% from taking a tub bath.

Vapor intrusion may also be a potential source of 2-butanone exposure, as vapor intrusion has been observed for several volatile organic chemicals (VOCs) with similar properties. EPA's compilation of four studies of background indoor air concentrations found a 79–91% detection rate for 2-butanone in 802 U.S. resident samples between 1990 and 2005 (EPA 2011). The background medians ranged from 2.7 to 6.5 $\mu g/m^3$, 95th percentiles ranged from 21 to 39 $\mu g/m^3$, and maximum values ranged from 76 to 890 $\mu g/m^3$. ATSDR extracted environmental data from 135 ATSDR reports evaluating the vapor intrusion pathway at 121 sites published between 1994 and 2009 (Burk and Zarus 2013). The data set contained the maximum measured 2-butanone indoor air data at 11 vapor intrusion sites and ranged from 0.06 to 96 $\mu g/m^3$ (ATSDR 2005a, 2005b). ATSDR's findings for 2-butanone from the 121 vapor intrusion sites generally fell within EPA's background ranges, although the 95th percentile was about 2 times greater than background, indicating some potential vapor intrusion impact on indoor air concentrations.

2-Butanone is a naturally occurring constituent in a variety of common foods (Del Rosario et al. 1984; Dumont and Adda 1978; Gordon and Morgan 1972; Grey and Shrimpton 1967; Keen et al. 1974; Kinlin et al. 1972; Lovegren et al. 1979; Takeoka et al. 1988). Ingestion of these foods will result in exposure to

2-butanone. Exposure to 2-butanone may also occur while smoking (Higgins et al. 1983; Osborne et al. 1956). Students taking undergraduate general chemistry laboratory courses may be also exposed to 2-butanone (Kolb 1988).

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Exposure to both 2-butanone and n-hexane or methyl-n-butyl ketone is possible in occupational settings and at hazardous waste sites; thus, neurological effects of n-hexane and methyl-n-butyl ketone may be greater with coexposure to 2-butanone. Likewise, occupational exposure or exposure at hazardous waste sites to a combination of 2-butanone and the haloalkanes, carbon tetrachloride, or chloroform, presents a greater risk for liver damage.

For the general population, high levels of exposure to 2-butanone may occur for those living near commercial settings where this compound is used. For example, the downwind 2-butanone concentration near a solvent recycling facility was measured at concentrations up to 94 ppm (Smoyer et al. 1971). High levels of exposure may also occur during the use of commercial coatings containing 2-butanone, especially when working in enclosed, unventilated spaces. Members of the general population living near hazardous waste sites and drawing their drinking water from groundwater sources may be exposed to high levels of 2-butanone through ingestion of contaminated water, although no information on the size of the population can be provided.

Occupational exposure to 2-butanone is expected to occur by inhalation and dermal contact. High levels of occupational exposure could occur during the loading and unloading of large quantities of this material during shipment and during the application of commercial coatings containing 2-butanone without adequate protection. According to the National Occupational Exposure Survey (NOES) conducted by the National Institute for Occupational Safety and Health (NIOSH) between 1980 and 1983, 1,221,587 workers, of which 201,308 were women, were potentially exposed to 2-butanone during that time period (NIOSH 1989). Of these workers, 84% (80% for the women) were exposed during the use of trade name products containing 2-butanone. More recent occupational survey data were not identified.

Similarly, recent occupational monitoring data were not identified for 2-butanone. A study of three companies involved in spray painting and spray gluing operations reported that, for 89 workers exposed to 2-butanone, the mean air concentration was 0.3 ppm (Whitehead et al. 1984). 2-Butanone was detected in the air of Cincinnati wastewater treatment plants in 1982; 3 of 17 samples were positive at concentrations ≤5.7 ppb (Dunovant et al. 1986). It has also been detected in the air above shale oil wastewaters (Hawthorne and Sievers 1984). The breathing zone air for workers at an organic solvent recycling plant averaged 11 ppm during drum decantation operations and 10 ppm during all other work activities (Kupferschmid and Perkins 1986). The ambient concentration was not greater than exposure limits of 200 ppm in any of these examples (NIOSH 1984). The concentrations of 2-butanone in air samples obtained from the Skylab, 1973–1974, ranged from 2.4 to 1,505 ppb (Liebich et al. 1975). Personal exposure to 2-butanone at a waste solvent incineration facility ranged from <0.01 to 1.2 ppm (Decker et al. 1983).