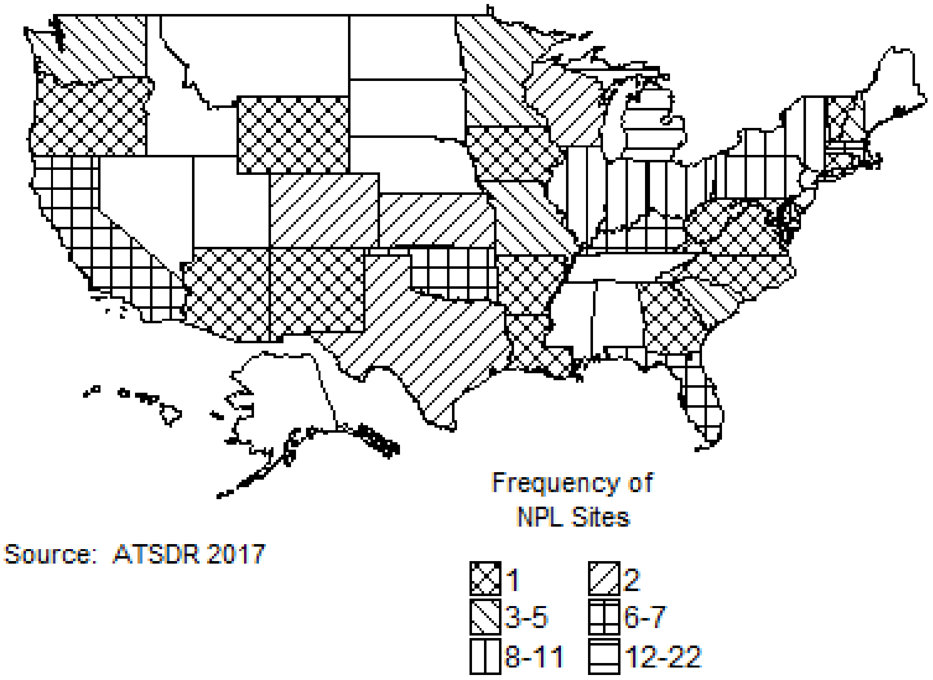
CHAPTER 5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Isophorone has been identified in at least 156 of the 1,854 hazardous waste sites that have been proposed for inclusion on the EPA National Priorities List (NPL) (ATSDR 2017). However, the number of sites in which isophorone has been evaluated is not known. The number of sites in each state is shown in Figure 5-1. Of these sites, all 156 are located within the United States

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



Source: ATSDR 2017

- Isophorone is used mainly as a solvent that is evaporated during or after use; therefore, most environmental releases are to the air.

- Isophorone can enter surface waters from industrial effluent discharges or from runoff from soils at hazardous waste or other contaminated sites.

- Isophorone disappears rapidly from air by hydroxyl radical reaction but may persist in surface waters for up to one month.

- The most likely routes of exposure for the general population is by inhalation of isophorone in air and ingestion of isophorone in water

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 isophorone 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 a 1987 edition of the United States International Trade Commission (USITC) publication on U.S. production and sales of synthetic organic chemicals (USITC 1987), Union Carbide (Institute, West Virginia) was the only domestic manufacturer of isophorone in 1987. A comparison of the list of isophorone manufacturers in USITC (1987) and USITC (1986) shows that Exxon Corporation (Bayway, New Jersey) also manufactured this chemical but discontinued production in 1985. Because of the limited number of domestic manufacturers of isophorone and their desire to maintain confidentiality, up-to-date information regarding the production volume of isophorone in the United States is not available. In 1973, 35 million pounds of isophorone were produced in the United States (Papa and Sherman 1981), and in 1980, approximately 20–30 million pounds were produced (CMA 1981). The decrease may be because of replacement of isophorone with less costly solvents (CMA 1981).

Isophorone can be prepared by: (1) passing acetone vapor over a catalyst bed of magnesium aluminate, zinc oxide-bismuth oxide, or calcium oxide under pressure at 300–400°C or (2) reacting acetone, water (up to 30%), and potassium hydroxide (∼1%) in a column under a pressure of about 35 atm and at a temperature of about 200°C (Papa and Sherman 1981). Commercial isophorone usually contains some unconjugated isomer (up to 5%) and small amounts (<l%) of xylitone (Papa and Sherman 1981). Isophorone tends to discolor on prolonged storage; stabilization against color formation can be provided by treatment with p-toluenesulfonic acid, acidified Fuller's earth, diazines, or diisopropylamine (Papa and Sherman 1981).

5.2.2 Import/Export

During 1984, 2,158 million pounds of isophorone were imported into the United States (HSDB 1988).

5.2.3 Use

Isophorone is a solvent for a large number of natural and synthetic polymers, resins, waxes, fats, and oils. Specifically, it is used as a solvent for concentrated vinyl chloride/acetate-based coating systems for metal cans, other metal paints, nitrocellulose finishes, printing inks for plastics, some herbicide and pesticide formulations, adhesives with food contract, and adhesives for plastics, poly(viny1) chloride and polystyrene materials (Papa and Sherman 1981). Isophorone also is an intermediate in the synthesis of 3,5-xylenol, 3,3,5-trimethylcyclohexanol (Papa and Sherman 1981), and plant growth retardants (Haruta et al. 1974). Of the total production, 45–65% is used in vinyl coatings and inks, 15–25% in agricultural formulations, 15–30% in miscellaneous uses and exports, and 10% as a chemical intermediate (CMA 1981).

5.2.4 Disposal

Isophorone may be disposed of by incineration, waste water treatment, or sanitary landfill (OHM-TADS 1988).

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).

Isophorone is released to the air mainly in urban centers, as a result of evaporation of solvents containing this chemical. Isophorone can enter surface waters from industrial effluent discharges or from runoff from soils at hazardous waste or other contaminated sites. Isophorone disappears rapidly in air by hydroxyl radical reaction (half-life <5 hours) but may persist in natural waters from several days to about a month.

Volatilization and sorption are not expected to be significant removal mechanisms from water. In soils, isophorone is expected to degrade microbially, but no rate data are available. Isophorone has been monitored in effluents (range <5–1,380 ppb), ambient water (range <0.6–100 ppb), drinking water (from contaminated surface water) (range 0.02–9.5 ppb), and soils at hazardous waste sites (range 0.16–6,500 ppm).

Occupational exposures occur mainly by inhalation and dermal contact and are documented most frequently in the printing trades. Air concentrations in screen printing facilities range from <0.47 to 25.7 ppm. A 1988 estimate by the National Institute for Occupational Safety and Health reported that 37,469 workers (9,211 of whom were female) were exposed to isophorone in both trade name products and chemical named products.

5.3.1 Air

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

Since isophorone is used mainly as a solvent that is evaporated during or after use, the vast majority of environmental releases are to the air. Use patterns indicate that most air releases are in urban centers, with a smaller percentage of release in rural areas. Nonetheless, very little ambient air monitoring data exist to confirm this, probably because of its short atmospheric lifetime (half-life <5 hours).

Apparently, a major source of isophorone in the environment is the printing industry, since these operations usually do not use emission control technologies to reduce emitted isophorone concentrations (Bierbaum and Parnes 1974; Kominsky 1981; Lee and Frederick 1981; Samimi 1982). Other industries (e.g., metal coating) that use similar ventilation methods (NIOSH 1978a) are major sources of atmospheric isophorone. Coal-fired power plants may also emit isophorone to the air, since isophorone has been detected in the fly ash of one such plant (Harrison et al. 1985).

Volatilization from surface waters is not expected to be a significant source of isophorone in the atmosphere, since this is anticipated to be a slow process (based on the Henry's law constant of 4.55×10^{-6} atm-m^3/mol).

Waste water treatment plants may, however, emit some isophorone from influent water to the air, particularly if gas stripping methods are used (Hawthorne and Sievers 1984; Hawthorne et al. 1985). Drinking water plants that practice aeration of influent water may also emit small amounts of isophorone to air.

5.3.2 Water

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

Little data are available to quantitatively estimate releases of isophorone to water. Available information is summarized below.

During isophorone manufacture, process water may contact the isophorone and carry some of it to waste water streams. During use of isophorone, paint spray booths that use water curtains, wash water, and process water all may contain isophorone. Isophorone has been detected in the United States in industrial effluent discharges (Bursey and Pellizzari 1982; Hawthorne and Sievers 1984; Hawthorne et al. 1985; Jungclaus et al. 1976), hazardous waste landfill leachate and runoff (Ghassemi et al. 1984; Hauser and Bromberg 1982; Stonebraker and Smith 1980), and urban runoff (Cole et al. 1984).

Specific industrial categories that produce wastewaters containing isophorone include timber products, petroleum refining, paint and ink, pulp and paper, automobile and other laundries, pharmaceuticals, foundries, transportation equipment, and publicly-owned treatment works (Bursey and Pellizzari 1982). It is likely that treated waters from these industries that are often discharged to surface waters will contain isophorone (Bursey and Pellizzari 1982).

5.3.3 Soil

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

The only direct measurements of isophorone in soil were found for samples taken from hazardous waste sites. Ghassemi et al. (1984) found isophorone in leachates from hazardous waste landfills, and Hauser and Bromberg (1982) detected the presence of isophorone in the "sediment/soil/water" of Love Canal. These studies suggest that isophorone also was present in the soil.

5.4 ENVIRONMENTAL FATE

5.4.1 Transport and Partitioning

Isophorone has a water solubility of 12,000 ppm, a log octanol/water partition coefficient of 1.67, a Henry's law constant of 4.55x10m^{-6} atm m^{3}-mol, a vapor pressure of 0.3 mm Hg at 20°C, a log sediment sorption coefficient of approximately 1.46, and a log bioconcentration factor (BCF) of 0.85.

Air. Isophorone is released to air and water from its manufacturing and use. Based on its water solubility, some isophorone may wash out of the atmosphere; however, only limited amounts will be washed out because of the short atmospheric half-life of isophorone. Particularly during the day, when hydroxyl radical (HO·) concentrations are highest, very little atmospheric transport will occur due to its fast reaction with HO·.

Water. In water, neither volatilization nor sorption to sediments is expected to be an important transport mechanism. The results of two EXAMS model runs and the value of the Henry's law constant (calculated from the solubility and the vapor pressure) suggest that volatilization will not be important in shallow ponds or in lakes. EXAMS is an environmental model that predicts the behavior of a chemical in surface waters (EPA 1985a). Using the code test data for a pond developed by the Athens Environmental Research Laboratory of EPA, the half-life for volatilization was calculated to be 104 days, while for a lake, the half-life was calculated to be 288 days. Input data included molecular weight, vapor pressure, Henry's law constant, octanol/water partition coefficient, sediment sorption coefficient, and water solubility. Equations correlating solubility or octanol/water partition coefficients with sorption partition coefficients (K_{oc}) were not developed using structures similar to isophorone, however, and the K_{oc} value entered into the EXAMS model thus should be viewed as tentative (EPA 1985a). The volatilization rates predicted by the EXAMS model appear to be consistent with the observation of Hawthorne and Sievers (1984), who reported that isophorone could be analyzed in wastewater by purge and trap methods but was not found in the air above the wastewater in a closed system without a purge.

Sediment and Soil. McFall et al. (1985) reported isophorone concentrations in sediments of Lake Pontchartrain, Louisiana, an estuary located in the Mississippi River delta.

Sediments containing isophorone were detected in the Inner Harbor Navigation Canal (IHNC), the Rigolets, and the Chef Menteur Pass. Concentrations in the overlying waters were not reported. Therefore, the sorption partition coefficient in these sediments could not be derived from these experimental data.

Other Media. The bioconcentration of isophorone in bluegill sunfish has been reported by Barrows et al. (1978, 1980) and Veith et al. (1980) (all reports used the same BCF value). These researchers reported a BCF of 7 (log BCF of 0.85) as determined in a continuous dilution flow-through system using ^{14}C-labeled isophorone. This value suggests that concentrations of isophorone in fish living in isophorone contaminated waters will not be more than an order of magnitude higher than concentrations in the water. Nonetheless, concentrations of isophorone have been found in fish in Lake Michigan tributaries and embayments (Camanzo et al. 1987) at concentrations ranging from below the detection limit (~0.02 mg/kg) to 3.61 mg/kg wet weight. McFall et al. (1985) also analyzed oysters from the IHNC and clams from the Rigolets and the Chef Menteur Pass in Lake Pontchartrain for isophorone. Oysters from the IHNC had detectable levels of isophorone (38 ppb dry weight), but clams did not; the detection limits were not specified and no BCF can be calculated with the data supplied. These data indicate, however, that isophorone can be found in aquatic organisms at mg/kg levels, although no correlation was found between the concentration of isophorone and lipid content in the organism (Camanzo et al. 1987).

5.4.2 Transformation and Degradation

Air. No studies were located regarding the rates or products of reaction of isophorone in the atmosphere. Isophorone does not significantly absorb light above wavelengths of 290 nm (Sadtler Index 1966 [UV #44]); hence, it is not expected to undergo direct photolysis. However, isophorone can react with photochemically produced NOx in the atmosphere (usually formed at higher concentrations in photochemical smogs) producing moderate eye irritation, NO_2, other oxidants (including ozone, various peroxy compounds, and free radicals), and formaldehyde as indicated in smog chamber studies (Altshuller and Bufalini 1971; Farley 1977; Levy 1973). The most significant reaction of isophorone in the atmosphere is probably its reaction with HO·.

Addition of HO· will occur at the double bond of the compound and may be followed by multiple reaction pathways (Atkinson 1985). Atkinson (1987) developed a method to estimate the HO· reaction rate based on structure. Using this method, an overall reaction rate of 81.5×10^{-12} cm^3 molecule-second was calculated. This reaction rate yields a half-life of 4.7 hours for an atmospheric 24-hour average HO· concentration of 0.5×10^6 molecules-cm (Atkinson 1985). In indoor air, HO· concentrations probably are significantly lower (Atkinson 1985); therefore, reaction half-lives of HO· with isophorone in indoor air probably will be much longer than in outdoor air. Thus, isophorone is expected to persist much longer in indoor air than in outdoor air unless the indoor/outdoor air exchange rate is high.

Water. The aerobic biodegradation of isophorone has been studied using sludge and waste water inocula as well as combined biological and physical treatment methods. Isophorone appears to biodegrade under most conditions simulating those in sewage treatment plants. No studies regarding biodegradation or abiotic reactions involving photolysis or oxidation of isophorone in surface and groundwater were located in the literature.

Aerobic biodegradation of isophorone appears to be possible in sewage sludge or settled domestic waste water. The exact conditions, however, appear to be important. For example, Tabak et al. (1981a, 1981b) reported 100% degradation of isophorone in 7 days using settled domestic waste water amended with 5 ppm of yeast extract. Price et al. (1974) reported that the equivalent of 42% theoretical oxygen demand for the compound was consumed in 20 days with a domestic wastewater seed without the yeast extract, and Kawasaki (1980) reported that isophorone was resistant to biodegradation in a test developed by the Japanese Ministry of International Trade and Industry (MITI). The MITI test is essentially a biological oxygen demand (BOD) test conducted over 14 days with a seed obtained from soil and sludge samples taken throughout Japan. The results are reported as a pass if 30% or more of the theoretical BOD is consumed and as a fail if <30% is consumed. During the operation of two model sewage treatment plants, Hannah et al. (1986) and McShane et al. (1987) reported that virtually all of the isophorone added to the influent water was removed during the activated sludge portion of the treatment process. The hydraulic detention times for both systems were on the order of several hours. None of the test concentrations were near the activated sludge EC_{50} of 100 ppm (Yoshioka et al. 1986). Some of the removal may have been due to adsorption to the sludge as Hannah et al. (1986) reported that the sludge from their process contained isophorone at concentrations that exceeded the influent water concentrations.

While the evidence presented in the literature cited above suggests that isophorone can be virtually completely removed under sewage treatment plant conditions, monitoring data indicate that isophorone is still present in treated wastewater and in ambient water.

This, in turn, suggests that the exact conditions under which isophorone is rapidly biodegraded or removed are not well understood. The presence of this compound in treated wastewater is indicative that the proper removal conditions were not employed for these systems, or that the input concentrations into sewage treatment plants were high enough that the capacity of the treatment plants were exceeded.

Sediment and Soil. No studies were located regarding the transformation of isophorone in soils. Based on the information presented above and the lack of any monitoring data that report isophorone in groundwater or soils (except for hazardous waste sites), it appears that isophorone may not be discharged to soils in large amounts, and the small amounts that are deposited may degrade rapidly in soil. Another explanation, however, is that there is a lack of studies determining isophorone content in soil.

5.5 LEVELS IN THE ENVIRONMENT

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

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

Media	Detection limit	Reference
Air	2 mg/m^3	NIOSH 1984
Water	2.2 μg/L	EPA 1982, 1987a
Soil/sediment	330 μg/kg	EPA 1987a
Whole blood	No method identified	

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

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

Table 5-2. Isophorone 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)	40	72.2	9,430	18	17
Soil (ppb)	2,500	4,300	14,600	22	17
Air (ppbv)			No data		

[a] Concentrations found in ATSDR site documents from 1981 to 2015 for 1,832 NPL sites (ATSDR 2017). Maximum concentrations were abstracted for types of environmental media for which exposure is likely. Pathways do not necessarily involve exposure or levels of concern.

5.5.1 Air

No ambient air monitoring for isophorone was located in the literature.

The estimated atmospheric half-life of isophorone, <5 hours, may account for the lack of monitoring data, since concentrations will decrease rapidly with distance from the source. Another explanation, however, is that no studies have been conducted that analyzed for isophorone in air.

5.5.2 Water

Isophorone has been detected in surface waters, sediments, drinking water, industrial effluents, urban runoff, and in runoff waters from hazardous waste sites. Table 5-3 summarizes the available data.

In general, isophorone is found in urban centers and appears to result from industrial activities. For example, its presence in the Delaware River near Philadelphia is the result of industrial effluents that are discharged into the sewer system (Hites 1979). The sewage is treated in Philadelphia's Northeast Sewage Treatment plant, which discharges its effluent into the Delaware River. Isophorone was detected in the Delaware River in the winter only; in the summer, biodegradation or other processes (e.g., sorption) may have removed it from the water column. Isophorone has been detected in the sediments of Lake Pontchartrain, which is located in the delta plain of the Mississippi River, its presence probably is due to

Table 5-3. Detection of Isophorone in Water

Media type	Location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Concentration (ppb) Mean	% Occurrence	Reference
Surface water	Delaware River	8/77–3/78	NS	Grab/composite	GC/MS	<0.6–3	NS	NS	Hites 1979
	Delaware River	Winter 1976–1977	18	Grab	GC/MS	Trace	NS	NS	Sheldon and Hites 1978
	Delaware River	Summer 1976	18	Grab	GC/MS	ND	ND	NA	Sheldon and Hites 1978
	Olentangy River, OH	NS	NS	Grab	GC/FID	<5	ND	0	Shafer 1982
	Potomac River by Quantico	1986	NS	Grab	GC/MS	<2	ND	0	Hall et al. 1987
Sediments	Lake Pontchartrain	5/80–6/80	10	Grab	GC/MS	0.9[a]–23	2.9	NS	McFall et al. 1985
Drinking water	Cincinnati, OH	NS	NS	NS	NS	0.02	NS	NS	EPA 1975
	New Orleans, LA	8/74–9/74	NS	Continuous adsorption	GC/MS	1.5–9.5	NS	NS	EPA 1974
	Philadelphia, PA	2/75–1/77	12	Grab	GC/MS	NS	NS	17	Keith et al. 1976
Effluents	Shale oil sites	7/81–12/82	NS	Grab	GC/MS	0.34–5.8[b]	NS	100	Suffet et al. 1980
	Tire manufacturing plant	NS	NS	Grab	GC/MS	40	NS	100	Hawthorne and Sievers 1984
	Unspecified effluent	NS	NS	NS	GC/MS	NS	NS	NS	Jungclaus et al. 1976
	Philadelphia sewage treatment plant influent	8/77–3/78	NS	Grab/composite	GC/MS	100	NS	NS	Perry et al. 1976
	Philadelphia sewage treatment plant effluent	8/77–3/78	NS	Grab/composite	GC/MS	10	NS	NS	Hites 1979
	Plastics effluents	NS	NS	Grab	GC/FID	40.5	NS	100	Shafer 1982
	Ship holding tank	NS	NS	Grab	GC/FID	<50	NS	0	Shafer 1982
	Secondary sewage effluent	NS	NS	Grab	GC/FID	120	NS	100	Shafer 1982
	Chemical industry final effluent	NS	NS	Grab	GC/FID	<5	NS	0	Shafer 1982

Table 5-3. Detection of Isophorone in Water

Media type	Location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb)		% Occurrence	Reference
						Range	Mean		
	Chemical manufacturing plant final effluent	NS	NS	Grab	GC/FID	<20	NS	0	Shafer 1982
	Timber products	NS	2[c]	NS	GC/MS	55–111	83	NS	Bursey and Pellizzari 1982
	Petroleum refining	NS	1[c]	NS	GC/MS	1,380	NS	NS	Bursey and Pellizzari 1982
	Paint and ink	NS	5[c]	NS	GC/MS	24–946	185	NS	Bursey and Pellizzari 1982
	Pulp and paper	NS	1[c]	NS	GC/MS	753	NS	NS	Bursey and Pellizzari 1982
	Auto and other laundries	NS	2[c]	NS	GC/MS	43–44	43	NS	Bursey and Pellizzari 1982
	Pharmaceuticals	NS	1[c]	NS	GC/MS	237	NS	NS	Bursey and Pellizzari 1982
	Foundries	NS	1[c]	NS	GC/MS	136	NS	NS	Bursey and Pellizzari 1982
	Transportation equip.	NS	2[c]	NS	GC/MS	28–318	173	NS	Bursey and Pellizzari 1982
	POTWs[d]	NS	15[c]	NS	GC/MS	4.2–114	11.5	NS	Bursey and Pellizzari 1982
Urban runoff	Washington DC	NS–7/82	86	Grab	NS	10	NS	4	Cole et al. 1984
Hazardous waste sites	Love Canal	8/80–10/80	NS	Grab	GC/MS	NS[f]	NS	NS	Hauser and Browberg 1982
	Valley of the Drums	1979	2[c]	Grab	NS	15–37[g]	26	NS	Stonebraker and Smith 1980
	11 Disposal sites	NS	8	Grab/composite	NS	29[h]	NS	12.5	Ghassemi et al. 1984
	Cooper Road site, NJ	NS	NS	NS	NS	NS[i]	NS	NS	VIEW database 1988
	Sheridan Disposal Services, TX	NS	NS	NS	NS	2,500[e]	NS	NS	VIEW database 1988
	Summit National site, OH	NS	NS	NS	NS	NS[g]	NS	NS	VIEW database 1988
	Unspecified site	NS	1	NS	NS	NS[g]	78	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	91	NS	CLSDB 1987
	Unspecified site	NS	2	NS	NS	NS[g]	315	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	1	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	360	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	538	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	48	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	12	NS	CLSDB 1987

Table 5-3. Detection of Isophorone in Water

Media type	Location	Sampling dates	Number of samples	Sample type	Analytical method	Concentration (ppb) Range	Concentration (ppb) Mean	% Occurrence	Reference
	Unspecified site	NS	1	NS	NS	NS[g]	20	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	48	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	137	NS	CLSDB 1987
	Unspecified site	NS	1	NS	NS	NS[g]	11	NS	CLSDB 1987
	Unspecified site	NS	2	NS	NS	NS[g]	57.6	NS	CLSDB 1987

[a] Average of 8 samples
[b] µg in air per mL wastewater from purge and trap analysis
[c] Number of positive samples
[d] Publicly owned treatment works
[e] Detected in groundwater
[f] Detected in sediment, soil, or water
[g] Detected in water
[h] Detected in leachate
[i] Detected in groundwater

GC/FID = gas chromatography/flame ionization detector; GC/MS = gas chromatography/mass spectroscopy; NA = not applicable; ND = not detected; NS = not specified the many industries that are situated along the Mississippi River and use the river water as process water (EPA 1974).

The presence of isophorone in drinking water is probably the result of using contaminated surface water as a source of drinking water. Of the three cities for which drinking water data are listed, Philadelphia receives its drinking water from the Delaware River, Cincinnati from the Ohio River, and New Orleans from the Mississippi River. These rivers receive numerous industrial effluents.

As listed in Table 5-3, isophorone has been detected in the effluents of a variety of industries. Levels in industrial effluents range from 4.2 to 1,380 ppb. Five reports of positive identifications were found in the open literature: a shale oil site; a tire manufacturing plant; sewer pump sample receiving wastes from phenolic resins manufacturing or processing, vinyl acetate, and polyvinylchloride process areas; final effluent from a sewage treatment system receiving wastes from plants producing plasticizers, butyl rubber, and olefin; and an unspecified effluent. The remaining samples listed in Table 5-3 are from an EPA database of over 4,000 analyses of organic pollutants in industrial wastewater made during the survey conducted in response to the consent decree between the Natural Resources Defense Council and EPA, June 7, 1976 (Bursey and Pellizzari 1982).

Isophorone also has been detected in urban runoff from Washington, DC (Cole et al. 1984).

5.5.3 Sediment and Soil

Isophorone has been identified in soil only at hazardous waste sites.

5.5.4 Other Media

Isophorone has been detected in oysters (but not in clams) in Lake Pontchartrain, Louisiana; the mean of eight samples of oysters from the Inner Harbor Navigation Canal section of the lake contained 38 ppb dry weight of isophorone. Hall et al. (1987) and De Vault (1985) did not detect isophorone in the fish in the Potomac River and Great Lakes Harbors and tributaries, respectively; in these cases, isophorone was not detected in the water either. Camanzo et al. (1987) reported finding isophorone in nearshore fish from 14 Lake Michigan tributaries and embayments; their results are presented in Table 5-4. Sampling was performed in 1983.

Table 5-4. Detection of Isophorone in Fish near Lake Michigan

Location	Fish	Sampling dates	Number of samples[a]	Mean concentration[b]	% Lipid
St. Joseph River	Common Carp	1983	5	ND[c]	23.1
	Smallmouth Bass	1983	7	0.74	3.7
Kalamazoo River	Common Carp	1983	4	0.12	5.9
	Largemouth Bass	1983	4	0.72	3.1
Grand River	Common Carp	1983	3	ND	4.0
	Channel Catfish	1983	6	ND	13.5
Muskegon River	Common Carp	1983	4	0.94	17.9
	Pumpkinseed	1983	3	0.40	2.4
White Lake	Common Carp	1983	4	0.66	15.4
	Bowfin	1983	5	ND	12.1
Pere Marquette River	Common Carp	1983	6	3.13	11.0
	Bowfin	1983	8	ND	13.5
Manistee River	Common Carp	1983	4	ND	10.5
	Bowfin	1983	4	0.76	11.5
Platte River	Common Carp	1983	3	2.32	14.7
	Northern Pike	1983	6	ND	3.5
Boardman River	Smallmouth Bass	1983	6	3.61	5.4
	Rock Bass	1983	3	1.44	3.5
Grand Traverse Bay	Common Carp	1983	3	0.47	16.2
	Lake Trout	1983	4	2.33	18.8
Manistique River	Smallmouth Bass	1983	5	1.03	4.5
	Northern Pike	1983	3	ND	2.1
Whitefish River	Common Carp	1983	11	0.88	16.4
	Rock Bass	1983	7	0.69	3.0
Escanaba River	Common Carp	1983	5	0.41	12.9
	Northern Pike	1983	6	0.48	2.9

Table 5-4. Detection of Isophorone in Fish near Lake Michigan

Location	Fish	Sampling dates	Number of samples[a]	Mean concentration[b]	% Lipid
Ford River	Northern Pike	1983	6	ND	3.0
	Rock Bass	1983	5	ND	3.1

[a] All samples are composites of the stated number of fish and were analyzed by gas chromatography/mass spectroscopy.
[b] mg/kg wet weight

ND = not detected

Isophorone was detected in fish samples from all but two of the sites; the mean of the samples that had detectable levels of the compound was 1.17 mg/kg wet weight. In addition to isophorone, the authors also reported the lipid content of the composite fish samples. No correlation could be found between isophorone concentration and lipid content.

Johansson and Ryhage (1976) reported that isophorone was present in one of three samples of the pharmaceutical clofibrate [ethyl 2-(4-chlorophenoxy)-2-methylpropionate], which lowers elevated serum lipids. The analysis was performed on samples available from Sweden, but clofibrate is also available in the United States. The concentration of isophorone present in samples of the drug available in the United States was not reported.

5.6 GENERAL POPULATION EXPOSURE

No ambient air monitoring data are available for isophorone; consequently, no potential inhalation exposures from ambient air can be estimated. Inhalation of isophorone from showering with contaminated water cannot be estimated from the available data (no measurements have been made).

Isophorone concentrations in surface waters and drinking waters are expected to vary considerably with season and with fluctuations in industrial discharges. Considering the dates of most of the positive identifications in surface and drinking water (middle to late 1970s), the effect of more stringent discharge limits in some industries since that time, and the probable seasonal, spatial, and temporal variations in concentrations, it is not possible to make an accurate estimate of ingestion intake of isophorone from drinking water without significant uncertainty. From the available data, it appears that long-term ingestion of isophorone from drinking water will be limited to those systems that receive their water from contaminated surface water sources and the seasonally averaged concentration in these waters probably will be <l ppb.

Isophorone, in addition to several other volatile compounds, was extracted from inflatable aquatic toys, providing an exposure pathway for children (Wiedmer et al. 2017).

Anjou and von Sydow (1967) reported that 0.2% of the essential oil of the American cranberry, *Vaccinium macrocarnon*, consisted of isophorone; they did not report the percentage of isophorone or the percentage of essential oil in whole cranberries. Without this information, it is not possible to estimate the concentration of isophorone in whole cranberries and compare the concentration to other sources.

However, frequent consumption of cranberry containing products is unlikely to represent significant intake of isophorone. Ingestion of isophorone from consumption of fish and shellfish cannot be robustly estimated from the available data (see Table 5-4).

Potential dermal exposure levels also are difficult to estimate from the available data. Dermal exposure from bathing in contaminated waters cannot be estimated without significant uncertainty. Other potential dermal exposures cannot be estimated with the available data.

Occupational exposures have been documented most frequently in the screen printing trade and are summarized in Table 5-5. During screen printing operations, both dermal and inhalation exposures can occur.

Breathing zone concentrations during screen printing range from <l to 25.7 ppm, while general area concentrations range from <l to 16 ppm. The exposure level varies significantly with the ventilation present in the work area. While exposure estimate for a specific screen printing operation is possible, no reasonable estimates can be made for other operations that may use isophorone because of lack of data.

The relative contributions of the exposure routes and sources are as follows. For persons exposed to isophorone in the workplace, total doses will probably be substantially higher than those exposed only to ambient air and drinking water, and their inhalation and dermal exposures for the occupationally exposed can be assumed to result exclusively from the workplace exposures. Inhalation and dermal exposure for persons not exposed to isophorone in the workplace will most likely result from showering or bathing, but only in locations that receive their drinking water from contaminated surface water sources. These exposures are expected to be very small. In locations that do not have the potential for isophorone in the drinking water, any ingestion, inhalation, or dermal exposure is unlikely.

Table 5-5. Occupational Monitoring of Isophorone

Company	Process	Sample type	Concentration (ppm) Range	Concentration (ppm) Mean[a]	Number of samples	% Positive	Reference
Pre-Finish Metals	Wire coating	Area	<1–3.37	1.13	24	33	NIOSH 1978a
Pre-Finish Metals	Wire coating	Personal	<1–3.37	1.13	19	42	NIOSH 1978a
Joel and Aronoff	Screen printing	Personal	<0.5–14	7.35	14	14	Lee and Fredrick 1981
Unspecified	Screen printing	Area	3.5–16	10.2	46	100	Samimi 1982
Unspecified	Screen printing	Personal	8.3–23	14.7	78	100	Samimi 1982
Electrocal	Screen printing	Area	0.70–1.22	0.957	6	100	Bierbaum and Parnes 1974
Electrocal	Screen printing	Personal	0.84–1.39	1.10	3	100	Bierbaum and Parnes 1974
Swinston Co.	Screen printing	Personal	<0.47–25.7	12.9	7	29	Kominsky 1981
Garden City Engraving	Screen printing	Area	<0.67–2.5	1.18	7	57	Salisbury 1983
Garden City Engraving	Screen printing	Personal	<0.58–3.4	1.42	8	75	Salisbury 1983

[a] Mean of the positive samples

5.7 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Populations with potentially high exposure include those occupationally exposed to isophorone (e.g., screen print workers, some adhesives formulators and users, some coatings manufacturing and use workers).

Individuals living near hazardous waste sites may be exposed to isophorone dermally, but probably not by inhalation. These individuals also may be exposed to isophorone by ingestion if they drink water from contaminated wells located down gradient from the site.