5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.1 PRODUCTION

TDI is manufactured via the dinitration of toluene with mixed acid to produce a mixture of 2,4- and 2,6-dinitro isomers in a 80:20 ratio. Catalytic reduction of these isomers under hydrogen pressure forms the corresponding diamines, which are then treated with phosgene to yield TDI, made up of an 80:20 mixture of isomers 2,4- and 2,6-TDI (HSDB 2012).

MDI is produced through a two-step process starting with the condensation reaction between aniline and formaldehyde in the presence of hydrochloric acid to yield MDA, followed by the phosgenation to MDI. The production of polymeric MDI also proceeds via this reaction, with the percent distribution of homologues and isomers being dependent on the ratio of aniline to formaldehyde, the acid concentration, and the reaction conditions (HSDB 2012).

The worldwide production of polyurethanes was around 15.9 million tons in 2007, which corresponds to a total consumption of 1.9 million tons of TDI (Geens et al. 2012). The worldwide production volume of MDI in 2008 was approximately 1.4 million tons (Gries and Leng 2013). Also in 2008, the demand for pure MDI and polymeric MDI was 192.1 and 1,418 million pounds, respectively, in the United States (EPA 2011a). The demand for TDI in 2008 in the United States was 425.2 million pounds (EPA 2011b). 2,4-TDI, 2,6-TDI, and 4,4'-MDI are listed by the EPA as High Production Volume (HPV) chemicals. Chemicals listed under the HPV Challenge Program were produced or imported into the United States in quantities >1 million pounds in 1990 and/or 1994 (HSDB 2012). The aggregated national production volumes reported for 2,4-TDI, 2,6-TDI, and 4,4'-MDI under the EPA's 2010 Inventory Update Rule were 10–<50, <500,000, and 100–<500 million pounds (EPA 2010). TDI (mixed isomers) had a reported aggregated national production volume of ≥1 billion pounds (EPA 2010).

TDI (mixed isomers), 2,4-TDI, and 2,6-TDI are chemicals that manufacturing and processing facilities would be required to report under Section 313 of the Emergency Planning and Community Right-to-Know Act (Title III of the Superfund Amendments and Reauthorization Act of 1986 [SARA]) (EPA 1998a). Tables 5-1, 5-2, and 5-3 list the production year, number of facilities, the state where each facility is located, and the range (in pounds) for each domestic manufacturer that reported the production or formulation of TDI (mixed isomers), 2,4-TDI, and 2,6-TDI, respectively in 2016 (TRI16 2017). The TRI category diisocyanates contains data for MDI and 20 other diisocyanates (not including TDI); however, since there is no way to parse out the data for MDI separately, it was not included.

Table 5-1. Facilities that Produce, Process, or Use Toluene Diisocyanate (Mixed Isomers)

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AR	1	100,000	999,999	6
AZ	1	No data	No data	No data
CA	11	100	9,999,999	6, 7, 8, 11
DE	2	10,000	99,999	6, 7
FL	3	10,000	999,999	6, 7
GA	6	10,000	999,999	6
IA	2	10,000	999,999	6, 7
IL	3	1,000	999,999	6, 7, 12
IN	6	1,000	9,999,999	6, 7
KS	2	1,000	9,999,999	6
KY	2	100,000	49,999,999	6, 9
LA	3	100,000	9,999,999	1, 4, 6, 12
MA	4	10,000	9,999,999	6, 7
MD	2	100,000	999,999	6, 7
ME	2	10,000	99,999	6
MI	5	10,000	9,999,999	6, 7, 9, 10, 11
MN	1	1,000	9,999	6, 7, 8
MO	5	100,000	999,999	6
MS	6	100,000	9,999,999	6, 7
NC	11	10,000	9,999,999	6, 7
NH	1	1,000	9,999	6
NJ	7	10,000	999,999	6, 7
NM	2	100,000	999,999	6, 7
OH	8	1,000	999,999	6, 7, 8, 9, 12
OR	1	100,000	999,999	6
PA	7	1,000	999,999	6, 7
PR	1	No data	No data	No data
SC	2	10,000	99,999	6
TN	4	1,000	999,999	6, 7, 9
TX	14	1,000	9,999,999	1, 3, 6, 7, 12
VA	4	100,000	9,999,999	6, 7, 9, 12
WA	2	10,000	999,999	6, 7

Table 5-1. Facilities that Produce, Process, or Use Toluene Diisocyanate (Mixed Isomers)

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
WI	2	100,000	999,999	6, 7
WV	1	1,000,000	9,999,999	6, 7, 9

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

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

Source: TRI16 2017 (Data are from 2016)

Table 5-2. Facilities that Produce, Process, or Use 2,4-Toluene Diisocyanate

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	1	10,000	99,999	7
AR	2	100,000	999,999	9, 12
CO	1	1,000,000	9,999,999	6, 8
CT	1	1,000	9,999	6
GA	2	100,000	999,999	10
IA	1	1,000	9,999	10
IL	1	No data	No data	No data
IN	2	1,000	999,999	6
KS	1	No data	No data	No data
KY	1	10,000	99,999	6
MA	1	10,000	99,999	6
MD	1	1,000	9,999	6, 7
MI	5	10,000	999,999	6, 7, 11
MN	1	10,000	99,999	12
MO	2	10,000	99,999	6, 7, 12
MS	4	0	9,999,999	6, 7, 12
NC	1	100,000	999,999	6
NE	1	100,000	999,999	6
NJ	3	10,000	99,999	6
NY	1	10,000	99,999	6, 7
OH	5	1,000	99,999	6, 7, 8, 12
PA	4	1,000	999,999	6, 7, 8
RI	1	No data	No data	No data
TN	2	1,000	999,999	6, 10, 11
TX	3	1,000	9,999,999	9, 12
UT	1	10,000	99,999	12
VA	1	10,000	99,999	8
WI	2	0	99	12
WV	1	100,000	999,999	2, 3, 7

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

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

Source: TRI16 2017 (Data are from 2016)

Table 5-3. Facilities that Produce, Process, or Use 2,6-Toluene Diisocyanate

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AR	1	10,000	99,999	12
CO	1	100,000	999,999	6, 8
GA	1	10,000	99,999	10
IL	1	No data	No data	No data
IN	1	10,000	99,999	6
KS	1	No data	No data	No data
MA	1	1,000	9,999	6
MD	1	1,000	9,999	6, 7
MI	4	10,000	999,999	6, 7, 8
MO	2	1,000	99,999	6, 7
MS	2	10,000	9,999,999	6, 7
NE	1	10,000	99,999	6
OH	5	100	99,999	6, 7, 8, 12
PA	1	10,000	99,999	6, 7, 1
TN	2	1,000	999,999	6, 7, 10, 11
TX	1	No data	No data	No data
WI	2	0	99	12
WV	1	10,000	99,999	2, 3, 6, 7

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

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

Source: TRI16 2017 (Data are from 2016)

Table 5-4. Facilities that Produce, Process, or Use Diisocyanates

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	32	1,000	9,999,999	1, 3, 4, 6, 7, 8, 10, 11, 12
AR	13	0	999,999	2, 4, 6, 7
AZ	12	1,000	999,999	6, 10
CA	63	100	9,999,999	2, 4, 6, 7, 8, 9, 10, 11
CO	8	10,000	9,999,999	6, 7, 8
CT	13	1,000	999,999	6, 7, 8, 9, 10, 11
DE	4	10,000	99,999	6, 7
FL	28	100	9,999,999	6, 7, 8, 9, 14
GA	54	1,000	9,999,999	2, 3, 4, 6, 7, 8, 9, 10
IA	20	1,000	999,999	6, 7, 8, 11, 12
ID	3	10,000	999,999	8, 12
IL	49	0	9,999,999	2, 3, 6, 7, 8, 9, 11, 12
IN	84	100	9,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14
KS	15	10,000	999,999	6, 7, 8, 11, 12
KY	25	10,000	9,999,999	1, 4, 6, 7, 8, 9, 10, 11
LA	14	0	49,999,999	1, 2, 3, 4, 6, 7, 9, 12
MA	23	1,000	9,999,999	6, 7, 8, 9, 11
MD	5	1,000	999,999	6, 7, 9, 11
ME	3	10,000	9,999,999	1, 5, 6, 8
MI	90	100	9,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14
MN	40	1,000	999,999	2, 3, 4, 6, 7, 8, 9, 11, 12
MO	55	100	9,999,999	2, 3, 6, 7, 8, 9, 10, 11, 12
MS	22	1,000	999,999	6, 7, 8, 10, 11, 12
MT	2	No data	No data	No data
NC	54	1,000	49,999,999	6, 7, 8, 9, 10, 11, 12
ND	2	10,000	9,999,999	7
NE	10	1,000	9,999,999	6, 8, 9, 10, 12
NH	5	1,000	999,999	2, 3, 6, 7, 8, 9
NJ	17	100	999,999	6, 7, 8, 11
NM	2	100,000	999,999	6
NV	7	10,000	999,999	6, 7, 12
NY	23	1,000	9,999,999	2, 3, 6, 7, 8, 9
OH	89	100	499,999,999	1, 5, 6, 7, 8, 9, 10, 11, 12
OK	15	1,000	999,999	6, 7, 8, 11
OR	23	0	9,999,999	1, 2, 3, 4, 6, 7, 8, 9, 10, 12, 13
PA	64	0	9,999,999	2, 3, 6, 7, 8, 9, 10, 11, 12
PR	2	1,000	9,999	12
RI	7	1,000	999,999	6, 7, 8, 9
SC	32	0	9,999,999	1, 3, 5, 6, 7, 8, 9, 10, 11, 12
SD	2	No data	No data	No data

Table 5-4. Facilities that Produce, Process, or Use Diisocyanates

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
TN	58	100	9,999,999	2, 3, 6, 7, 8, 9, 11, 12
TX	85	100	499,999,999	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12
UT	14	1,000	9,999,999	2, 3, 6, 7, 8, 9, 10, 12
VA	20	1,000	999,999	6, 7, 8, 9, 10, 11, 12
VT	1	No data	No data	No data
WA	11	1,000	9,999,999	6, 7, 11, 12
WI	71	1,000	9,999,999	2, 3, 6, 7, 8, 9, 10, 11, 12
WV	13	1,000	9,999,999	2, 3, 6, 7, 8, 9, 11

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

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

Source: TRI16 2017 (Data are from 2016)

Manufacturers are required to report Toxics Release Inventory (TRI) data to satisfy EPA requirements. The TRI data should be used with caution since only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list.

5.2 IMPORT/EXPORT

U.S. imports of mixed isomers of TDI were 984,000 kg (2.1 million pounds) in 1989, and decreased to 1,000 kg (2,200 pounds) in 1996 but increased again to 15 million kg (32 million pounds) in 2006; 2008 imports were reported as 500,000 kg (1.1 million pounds) (NTP 2011). U.S. imports of unmixed isomers of TDI were reported as 426,000 kg (939,000 pounds) in 1989, and reached a low of 9,000 kg (19,800 pounds) in 1998. U.S. imports of unmixed isomers peaked at 1.3 million kg (2.8 million pounds) in 2004; 2008 imports were 130,000 kg (286,000 pounds). U.S. exports of mixed isomers of TDI were 62 million kg (125 million pounds) in 1989, rising to 277 million kg (609 million pounds) in 2003. U.S. exports of unmixed isomers of TDI peaked in 1994 at 46 million kg (101 million pounds), falling to a low of 3.9 million kg (8.6 million pounds) in 2008 (NTP 2011).

It was reported that 5% of the total U.S. production volume of MDI was exported in 2000 (HSDB 2012). No export data could be located for MDI in the available literature.

5.3 USE

TDI and MDI have widespread commercial use due to their reactivity and versatility. TDI and MDI and their related polyisocyanates make up >90% of the commercial market (EPA 2011a). Commercial- grade TDI is made up of an 80:20 mixture of isomers 2,4- and 2,6-TDI and represents >95% of TDI industrial use (NIOSH 1989). Technical MDI products vary in composition and consist of several MDI isomers and oligomeric derivatives with increasing number of aromatic rings (Bobeldijk et al. 2008).

Diisocyanates, such as MDI and TDI, are generally supplied as raw materials to formulators who use their reactivity to combine them with other chemicals to create various polyurethanes with a wide diversity of applications (EPA 2011a, 2011b).

TDI is a widely used industrial intermediate in the manufacture of polyurethane products (Bilban 2004). In the presence of amines, TDI reacts rapidly with polyols to form polyurethane foam for the furniture, bedding, and automotive industries (Austin 2007).

MDI, polymeric MDI, and TDI are used predominantly in the production of flexible and rigid polyurethane foams. Rigid foams are mainly used for insulation, while flexible foams are used for cushioning. A smaller amount of the total production volume of MDI, polymeric MDI, and TDI is used in the non-foam polyurethane sector, including coatings, adhesives, binders, and sealants (EPA 2011a, 2011b).

Prior to reaching the consumer market, the majority of polyurethane products made with TDI and MDI undergo a curing process (process by which TDI and MDI react with other product components to form polyurethane). However, polyurethane products such as spray foams, coatings, sealants, and adhesives may be sold and used containing uncured TDI and MDI (EPA 2011a, 2011b). In general, polyurethane products sold to the consumer have low concentrations of uncured TDI and MDI and are generally accompanied by product safety information.

5.4 DISPOSAL

TDI is designated with an EPA hazardous waste number U223, and therefore, generators of waste containing this contaminant must conform with EPA regulations in storage, transport, treatment, and disposal (HSDB 2012).

TDI and MDI wastes from distillation equipment are preferably sent to special waste incinerators for burning. Hydrolysis reaction products of TDI and MDI contained in waste waters can be biodegraded by treatment with activated sludge. Recommended methods of TDI and MDI disposal include incineration, and alkaline hydrolysis. Disposal to landfills is not recommended (HSDB 2012).

A study was conducted to assess the effectiveness of using wet sand in the event of a spill to detoxify TDI *in situ*. A 30-L container holding 5 kg of TDI was covered with a mixture of 30 kg of sand and 5 kg of water at ambient temperature. After 24 hours, it was observed that only 5.5% of the TDI remained unreacted. The reaction degradation product, TDA, was not present above the detection limit (10 ppb) (Duff 1983).

Another study described a procedure to decontaminate diisocyanates by which liquid TDI or MDI was added to a decontamination solution containing water (90%), concentrated ammonia solution (8%), and liquid detergent (2%) to effect safe disposal (Duff 1983).

The EPA proposed “low part per million concentration level” criteria of 10 ppm for TDI, which would allow a pronouncement that the spilled TDI residues treated *in situ* could be considered nonhazardous, if the criteria are achieved (Duff 1983).