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

5.1 PRODUCTION

Tables 5-1 and 5-2 list the facilities in each state that manufacture or process manganese, the intended use, and the range of maximum amounts of manganese that are stored on site. The data listed in Tables 5-1 and 5-2 are derived from the Toxics Release Inventory (TRI09 2011). Only certain types of facilities were required to report. Therefore, this is not an exhaustive list.

Manganese is an abundant element comprising about 0.1% of the earth's crust (Graedel 1978). It does not occur naturally as a base metal, but is a component of over 100 minerals, including various sulfides, oxides, carbonates, silicates, phosphates, and borates (NAS 1973). The most commonly occurring manganese-bearing minerals include pyrolusite (manganese dioxide), rhodocrosite (manganese carbonate), and rhodanate (manganese silicate) (EPA 1984; NAS 1973; Windholz et al. 1983).

Most manganese ore is smelted in electric furnaces to produce ferromanganese, a manganese-iron alloy widely used in the production of steel (EPA 1984; NAS 1973). Approximately 2 tons of manganese ore are required to make 1 ton of ferromanganese (NAS 1973). Production of manganese metal is achieved by aluminum reduction of low iron-content manganese ore, and electrolytically from sulfate or chloride solution (Lewis 2001). Manganese with <0.1% metallic impurities can be produced electrolytically from a manganese sulfate solution (EPA 1984; Lewis 2001).

Manganese compounds are produced either from manganese ores or from manganese metal. For example, manganese chloride is produced by the reaction of hydrochloric acid with manganese oxide (Pisarczyk 2005). Manganese carbonate and manganese sulfate are produced by dissolving manganese carbonate ore (rhodochrosite) or Mn(II) oxide in sulfuric acid (Pisarczyk 2005). Potassium permanganate may be manufactured by the one-step electrolytic conversion of ferromanganese to permanganate, or by a two-step process involving the thermal oxidation of manganese(IV) dioxide of a naturally occurring ore into potassium manganate(VI), followed by electrolytic oxidation to permanganate (Pisarczyk 2005).

Most manganese is mined in open pit or shallow underground mines (EPA 1984; NAS 1973). Manganese ores were previously mined in the United States, but no appreciable quantity has been mined in the United States since 1978 (USGS 2007). The only mine production of manganese in the United States consisted of small amounts of manganiferous material having a natural manganese content of <5%. This type of

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	6	0	99,999	1, 5, 12, 13, 14
AL	113	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AR	75	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AZ	44	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CA	123	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CO	42	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
CT	31	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
DE	6	100	999,999	1, 3, 4, 5, 8, 10
FL	50	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
GA	78	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14
HI	7	0	99,999	1, 2, 3, 4, 5, 7, 8, 9, 12
IA	113	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ID	15	0	9,999,999	1, 3, 4, 5, 7, 8, 9, 12, 13
IL	194	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
IN	192	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	61	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KY	113	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
LA	70	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MA	42	0	49,999,999	1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14
MD	44	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ME	25	0	999,999	1, 2, 3, 5, 6, 8, 9, 11, 12, 13
MI	173	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MN	63	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	85	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MS	42	0	9,999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
MT	11	10,000	999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
NC	104	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ND	19	0	9,999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
NE	49	0	49,999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
NH	17	0	49,999,999	1, 2, 4, 5, 7, 8, 9, 11, 12, 13
NJ	73	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
NM	9	1,000	9,999,999	1, 2, 3, 5, 6, 8, 9, 11, 12, 14
NV	39	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
NY	106	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OH	249	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	83	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
OR	65	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PA	234	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PR	14	0	999,999	2, 3, 4, 7, 8, 9, 11, 12
RI	16	0	999,999	2, 3, 4, 8, 9, 11, 12
SC	70	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
SD	36	0	49,999,999	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14
TN	114	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	175	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	71	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
VA	61	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
VT	4	0	999,999	2, 4, 7, 11, 12
WA	73	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WI	143	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	49	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WY	12	0	999,999	1, 2, 3, 5, 8, 9, 11, 12, 13, 14

[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: TRI09 2011 (Data are from 2009)

Table 5-2. Facilities that Produce, Process, or Use Manganese Compounds

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	19	0	49,999,999	1, 2, 3, 5, 7, 8, 10, 11, 12, 13, 14
AL	155	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AR	82	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AZ	72	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
CA	115	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CO	72	0	499,999,999	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CT	36	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
DC	3	1,000	99,999	12
DE	39	0	9,999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
FL	103	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
GA	109	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
HI	6	100	999,999	1, 5, 7, 9, 10
IA	101	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ID	38	0	49,999,999	1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
IL	204	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
IN	187	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	75	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KY	97	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
LA	66	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MA	33	0	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
MD	76	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ME	19	0	9,999,999	1, 5, 6, 8, 12, 13, 14
MI	182	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MN	73	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	90	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MS	78	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MT	27	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14
NC	131	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ND	24	1,000	9,999,999	1, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14
NE	59	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
NH	14	0	99,999	1, 2, 3, 5, 7, 8, 9, 12, 13
NJ	95	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
NM	36	0	10,000,000,000	1, 3, 4, 5, 7, 9, 12, 13, 14
NV	42	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
NY	123	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OH	292	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

Table 5-2. Facilities that Produce, Process, or Use Manganese Compounds

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
OK	61	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OR	54	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PA	265	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PR	23	0	999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12
RI	5	10,000	999,999	8, 11
SC	111	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
SD	17	0	9,999,999	1, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TN	151	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	211	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	88	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
VA	76	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
VT	5	0	99,999	1, 5, 7, 8
WA	80	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WI	113	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	72	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WY	26	0	999,999	1, 3, 4, 5, 7, 9, 12, 13, 14

[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: TRI09 2011 (Data are from 2009)

material was produced in South Carolina for use in coloring brick (USGS 2007). Essentially all manganese ore used in manganese production in the United States is now imported (USGS 2007).

Currently, there are 3,703 facilities in the United States that indicate that they produce, process, or use manganese (TRI09 2011). These facilities are scattered across the United States, with the largest numbers in Ohio (249), Pennsylvania (234), and Illinois (194). Over 4,300 facilities are involved in the distribution or use of manganese or manganese compounds (TRI09 2011). Tables 5-1 and 5-2 list the number of facilities in each state, the ranges of the maximum amounts stored at each facility, and the uses of the material (TRI09 2011).

The organomanganese compound methylcyclopentadienyl manganese tricarbonyl (MMT) is produced in either of the following ways: via the reaction of manganous chloride, cyclopentadiene, and carbon monoxide in the presence of manganese carbonyl and an element of group II or IIIA, or via the reaction of methylcyclopentadiene with manganese carbonyl (EPA 1984; Sax and Lewis 1987). According to data submitted to the EPA by the American Chemistry Council Petroleum Additives Panel, MMT is manufactured by adding methylcyclopentadienyl dimer to a dispersion of sodium metal in diethylene glycol dimethyl ether under a nitrogen environment (EPA 2006b). Keeping the mixture at elevated temperature yields sodium-methylcyclopentadienyl, which is an intermediate in the reaction process. Manganese chloride is added to the stirred mixture containing the sodium methylcyclopentadienyl intermediate. The reaction eventually yields bis(methylcyclopentadienyl)manganese as a second intermediate of the reaction process. The reaction vessel is then pressurized with carbon monoxide, which results in the formation of MMT, which is separated from the reaction mixture via vacuum distillation (EPA 2006b).

No production data from facilities that manufacture or process MMT were found. According to data from the 2007 Directory of Chemical Producers, only one company located in Orangeburg, South Carolina produces MMT in the United States (SRI 2007).

Mn(II) dipyridoxyl diphosphate (MnDPDP), or mangafodipir trisodium, is classified as a drug or therapeutic agent, and no production data were found for it.

5.2 IMPORT/EXPORT

The United States does not produce manganese and is 100% import reliant (USGS 2007). Import and export data for manganese are provided in Table 5-3. Demand for manganese metal comes primarily from the aluminum and steel industry (USGS 2007). Manganese consumption in 2007 was about 13% lower than that of 2006, owing to constant demand by the domestic steel industry and reduction of producer and consumer stocks. From January through August of 2007, domestic steel production was 1.4% lower than that for the same period in 2006 (USGS 2008). The United States imports the bulk of its manganese ore from Gabon, 65%; South Africa, 19%; Australia, 7%; Ghana, 2%; and other nations, 7% (USGS 2007). Ferromanganese is imported from South Africa, 51%; China, 14%; Mexico, 6%; Republic of Korea, 5%; and other nations, 24% (USGS 2007).

There were no data located regarding the import or export of MMT or mangafodipir.

5.3 USE

Metallic manganese (ferromanganese) is used principally in steel production to improve hardness, stiffness, and strength. It is used in carbon steel, stainless steel, high-temperature steel, and tool steel, along with cast iron and superalloys (EPA 1984; NAS 1973). According to data obtained from the U.S. Geological Society (USGS), manganese ore was consumed primarily by eight firms with plants principally in the east and midwest United States (USGS 2008). The majority of ore consumed was associated with steel production, directly in pig iron manufacture and indirectly through upgrading ore to ferroalloys. Additional quantities of ore were used for nonmetallurgical purposes such as production of dry cell batteries, in plant fertilizers and animal feed, and as a brick colorant. Manganese ferroalloys were produced at two smelters, although one operated sporadically throughout the year (USGS 2008). Construction, machinery, and transportation end uses accounted for approximately 24, 10, and 10%, respectively, of manganese demand (USGS 2008). Most of the rest went to a variety of other iron and steel applications. The value of domestic consumption, estimated from foreign trade data, was about $730 million (USGS 2008).

Manganese compounds have a variety of uses. Manganese dioxide is commonly used in production of dry-cell batteries, matches, fireworks, porcelain and glass-bonding materials, amethyst glass, and as the starting material for production of other manganese compounds (EPA 1984; NAS 1973; Venugopal and Luckey 1978). Manganese chloride is used as a precursor for other manganese compounds, as a catalyst in the chlorination of organic compounds, in animal feed to supply essential trace minerals, and in

Table 5-3. Manganese Import/Export Data for 2003–2007

	2003	2004	2005	2006	2007
Imports for consumption[a]					
Manganese ore	347	451	656	572	610
Ferromanganese	238	429	255	358	322
Silicomanganese	267	422	327	400	390
Exports[a]					
Manganese ore	18	123	13	2	2
Ferromanganese	11	9	14	22	33

[a]Data in thousand metric tons gross weight

Source: USGS 2008

dry-cell batteries (EPA 1984). Manganese sulfate is used primarily as a component of fertilizer (60% of total consumption) and as a livestock supplement (30% of total consumption); it is also used in some glazes, varnishes, ceramics, and fungicides (EPA 1984; Windholz et al. 1983). Potassium permanganate's oxidizing power allows it to be used as a disinfectant; an antialgal agent; for metal cleaning, tanning, and bleaching; and as a water purification agent (Lewis 2001). Another common source of manganese is found in the street drug "Bazooka". It is a cocaine-based drug contaminated with manganese-carbonate from free-base preparation methods (Ensing 1985).

MMT is a fuel additive developed in the 1950s to increase the octane level of gasoline and thus improve the antiknock properties of the fuel (Davis 1998; EPA 1984; Lynam et al. 1990; NAS 1973). MMT was introduced into Canada in 1976 and its use increased so substantially that it completely replaced tetraethyl lead in gasoline in that country in 1990 (Zayed et al. 1999a). The major refiners in Canada have voluntarily stopped using MMT, out of concern that its use may harm on-board diagnostic equipment (OBD), which monitors the performance of emissions control devices in the vehicle (ICCT 2004). As a result, as much as 95% of Canadian gasoline is now MMT-free (ICCT 2004). MMT was used as an additive in leaded gasoline in the United States; however, EPA banned its use in unleaded gasoline in 1977 (EPA 1978, 1979a, 1981). In 1995, the ban on MMT use in unleaded gasoline was lifted, and a court decision ordered EPA to register the product for use as a fuel additive (EPA 1995a). Recent data suggest that MMT is currently used only sparsely in the developed world including the United States, although exact quantities are not known (ICCT 2004). Historical data suggest that approximately 70 million pounds of MMT were sold for use in leaded gasoline in the United States between 1976 and 1990 (Veysseyre et al. 1998).

Mangafodipir trisodium (MnDPDP) is used as both a liver- and pancreas-specific contrast agent for magnetic resonance imaging (MRI); it improves lesion detection in MRI of these organs by selectively enhancing the normal parenchyma, but not lesions, so that the contrast between tumorous and normal tissue is increased (Federle et al. 2000).

5.4 DISPOSAL

Manganese is listed as a toxic substance under Section 313 of the Emergency Planning and Community Right to Know Act (EPCRA) under Title III of the Superfund Amendments and Reauthorization Act (SARA) (EPA 1998). Disposal of wastes containing manganese is controlled by a number of federal regulations (see Chapter 8).

Disposal of waste manganese into water requires a discharge permit from the EPA (see Chapter 8), but disposal of solid wastes such as manganese metal or manganese compounds is not regulated under current federal law. There are incomplete federal records of this disposal because most, but not all, solid manganese wastes are disposed of by being deposited on land or by being trucked to off-site disposal facilities (TRI09 2011). The total amount of waste manganese disposed of in this way in 2009 was approximately 50 million pounds (TRI09 2011) (see Tables 6-1 and 6-2).

Manganese and other metals are commonly recycled for future use. In 1998, 218,000 metric tons of manganese were estimated to have been recycled from old scrap, of which 96% was from iron and steel scrap (USGS 2001). In 2007, the USGS reported that manganese was recycled incidentally as a minor constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible (USGS 2008). No quantitative statistics were provided regarding the amount recovered from steel slag.

No information on disposal of MMT was located.