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

5.1 PRODUCTION

Hydrogen Sulfide. Hydrogen sulfide is produced in technical (98.5%) and purified (99.5% minimum) grades (Lewis 2007). It is commercially available by two typical approaches: recovery from gas mixtures and chemical means. Natural gas and gases associated with crude oil contain varying amounts of hydrogen sulfide from trace amounts to 70–80% (Pouliquen et al. 1989). Recovery of hydrogen sulfide from natural gas, manufactured gas operations, or as a byproduct of petroleum refining is the main non-natural source of hydrogen sulfide (Beauchamp et al. 1984; Lewis 2007). These recovery processes can be categorized into several methods, including chemical and physical absorption, dry oxidation to form sulfur or oxides (Clause process), and liquid oxidation to form oxides (Ferrox process) (Beauchamp et al. 1984).

Hydrogen sulfide production by chemical reaction can involve reacting sulfur vapor either with a hydrocarbon (Pouliquen et al. 1989) or with hydrogen gas (H_2) at a specific temperature and pressure (Lewis 2007). It can also be produced by the hydrogen reduction or acid decomposition of a sulfide (Pouliquen et al. 1989), such as the reaction of dilute sulfuric acid on a sulfide (i.e., iron sulfide) (Lewis 2007). Another method of hydrogen sulfide production, which accounts for >90% of the sulfur in crude oil, is hydrodesulfurization, in which gas-oil and coke distillate fractions are passed through a fixed-bed catalyst in the presence of hydrogen. Approximately 80–90% of the sulfur-containing compounds (mostly acyclic and cyclic sulfides) are converted into hydrogen sulfide by this process (Beauchamp et al. 1984; Weil and Sandler 1997).

Table 5-1 lists the facilities in each state that manufacture, process, or use hydrogen sulfide as well as the volume ranges that are stored on-site. There are 520 facilities that produce or process hydrogen sulfide in the United States (TRI14 2015).

Carbonyl Sulfide. Carbonyl sulfide is produced as 97.5% minimum purity grade (HSDB 2007). It occurs as a byproduct of carbon disulfide production (EPA 1994c, 1994d; Weil and Sandler 1997) and is produced as an impurity in natural gas and refinery gases as well as from the combustion of sulfur-containing fuels. Carbonyl sulfide can result from the pyrolysis of carbonaceous fuels with oxygen, steam, and sulfur compounds (Lay et al. 2012).

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	2	100	99,999	
AL	30	0	999,999	1, 2, 3, 5, 6, 12, 13, 14
AR	17	0	49,999,999	1, 5, 6, 9, 12, 13, 14
CA	22	0	9,999,999	1, 2, 3, 5, 6, 7, 8, 13, 14
CO	3	0	499,999,999	1, 2, 5, 12, 13, 14
DE	4	0	499,999,999	1, 2, 5, 6, 7, 12
FL	13	0	9,999	1, 5, 14
GA	22	0	9,999,999	1, 2, 3, 5, 6, 12, 13
HI	2	1,000	99,999	1, 2, 3, 5, 6, 12, 13, 14
IA	9	100	9,999	1, 5
ID	4	100	9,999,999	1, 5, 14
IL	18	0	999,999,999	1, 2, 3, 5, 6, 7, 12, 13, 14
IN	13	0	9,999,999	1, 5, 7, 13, 14
KS	10	0	99,999,999	1, 5, 6, 7, 9, 13, 14
KY	9	0	999,999	1, 2, 5, 6, 12, 13, 14
LA	45	0	99,999,999	1, 2, 3, 5, 6, 7, 9, 10, 12, 13, 14
MA	2	10,000	99,999	9
MD	3	0	9,999	1, 5, 13
ME	6	0	99,999	1, 5
MI	6	0	999,999	1, 3, 4, 5, 6, 12, 13, 14
MN	9	0	49,999,999	1, 5, 12, 13, 14
MO	7	0	9,999,999	1, 3, 5, 6, 9, 11, 14
MS	13	0	99,999	1, 2, 5, 6, 12, 13, 14
MT	6	1,000	99,999	1, 2, 3, 4, 5, 6, 8, 9, 13, 14
NC	11	0	9,999,999	1, 5, 13
ND	6	0	9,999,999	1, 3, 5, 6, 9, 13, 14
NE	8	100	99,999	1, 5, 7, 12
NJ	5	0	999,999	1, 2, 5, 6, 13, 14
NM	6	0	99,999	1, 5, 6, 13, 14
NV	1	0	0	0
NY	7	0	99,999	1, 5, 9, 12, 13
OH	20	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14
OK	11	0	99,999	1, 3, 4, 5, 6, 12, 13, 14
OR	6	0	99,999	1, 5, 12
PA	14	0	99,999,999	1, 2, 3, 5, 10, 13, 14
PR	4	10,000	999,999	1, 2, 5, 7
SC	8	0	999,999	1, 5, 13, 14
SD	2	10,000	99,999	1, 5, 14

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
TN	11	0	999,999	1, 2, 4, 5, 13, 14
TX	76	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
UT	5	1,000	9,999,999	1, 2, 3, 5, 6, 10, 12, 13, 14
VA	8	0	999,999	1, 5, 6, 13
WA	16	0	49,999,999	1, 2, 3, 5, 6, 7, 12, 13, 14
WI	13	0	99,999	1, 5, 6, 12, 13, 14
WV	2	1,000	99,999	1, 3, 5, 6, 13
WY	5	1,000	9,999	1, 3, 5, 6, 7, 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: TRI14 2015 (Data are from 2014)

Carbonyl sulfide can also be found in tobacco smoke as well as emissions from diesel engines and the coal gasification process (NJDEP 2009). Additionally, carbonyl sulfide is found in numerous natural sources, including volcanic gases, petroleum crude oil, sulfurous waters, salt marshes, and soils (EPA 1994c). It can also emanate from deciduous and coniferous trees (EPA 1994c).

Table 5-2 lists the facilities in each state that manufacture, process, or use carbonyl sulfide as well as the volume ranges that are stored on-site. There are 134 facilities that produce or process carbonyl sulfide in the United States (TRI14 2015).

5.2 IMPORT/EXPORT

No data on import or export volumes for hydrogen sulfide or carbonyl sulfide are available.

5.3 USE

Hydrogen Sulfide. Hydrogen sulfide has a variety of industrial uses. Its major use is in the production of elemental sulfur and sulfuric acid. Sulfur recovered from the treatment of sour gas in 1986 accounted for 14 million tons, or 25% of total world sulfur production. In 1995, the production of sulfuric acid was estimated to consume $1.1x10^5$ metric tons of hydrogen sulfide. Hydrogen sulfide is used to prepare inorganic sulfides (such as sodium sulfide and sodium hydrosulfide) which are used in the manufacture of dyes, rubber chemicals, pesticides, polymers, plastic additives, leather, and pharmaceuticals. It is also used in the manufacture of metal sulfides and thioorganic compounds and is an intermediate for sulfuric acid and elemental sulfur production. Hydrogen sulfide is used in the purification of nickel, manganese, hydrochloric acid, and sulfuric acid; in catalyst activation and poisoning; in the treatment of metallic surfaces; and as a source of hydrogen. It is used in metallurgy, in the production of heavy water for the nuclear industry, and as an analytical reagent. In extreme pressure lubricants and cutting oils, hydrogen sulfide is used as an additive. Hydrogen sulfide is also used as an agricultural disinfectant. It is not registered as a pesticide in the United States (Beauchamp et al. 1984; Bingham et al. 2001; Lewis 2007; Sittig 2002; Weil and Sandler 1997). Recently hydrogen sulfide was reported to conduct electricity with zero resistance at -70 °C when subjected to high pressure (approximately 1.5 million atmospheres), which suggests that it has potential as a conventional high temperature superconducting material (Cartlidge 2015; Drozdov et al. 2015).

Table 5-2. Facilities that Produce, Process, or Use Carbonyl Sulfide

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	1	0	99	1, 5
AL	4	0	9,999	1, 5, 6, 12, 13, 14
AR	1	1,000	9,999	1, 3, 5, 6
CA	14	0	9,999,999	1, 3, 5, 6, 13, 14
DE	2	10,000	9,999,999	1, 3, 5, 6
HI	1	0	99	1, 13
IL	6	0	9,999,999	1, 3, 4, 5, 6, 13, 14
IN	7	0	999,999	1, 5, 12
KS	6	0	999	1, 5, 14
KY	3	0	9,999	1, 5
LA	19	0	999,999	1, 3, 5, 6, 7, 12, 13, 14
MI	1	100	999	1, 5
MN	3	100	9,999	1, 2, 3, 5, 6, 13
MO	1	0	99	1, 5
MS	3	100	999,999	1, 5, 6, 12
MT	4	0	9,999	1, 5, 6, 12, 13, 14
ND	2	0	9,999	1, 5, 13, 14
NM	1	0	99	1, 5
NV	1	0	99	1, 5
NY	2	0	99	1, 5
OH	6	0	9,999	1, 3, 5, 13
OK	4	0	999	1, 5, 12, 14
PA	2	1,000	9,999,999	1, 5, 12, 13
SC	2	0	99	1, 5, 12
TN	3	0	999	1, 5, 6, 13, 14
TX	25	0	9,999,999	1, 2, 3, 5, 6, 112, 13, 14
UT	3	0	999	1, 5
WA	6	0	999,999	1, 5, 13
WI	1	100	999	1, 5
WY	2	0	999	1, 5

[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: TRI14 2015 (Data are from 2014)

Carbonyl Sulfide. Carbonyl sulfide has few commercial uses; it is primarily used in small scale chemical syntheses (Lay et al. 2012). Carbonyl sulfide is a chemical intermediate in the manufacture of thiocarbamate herbicides (EPA 1994d; Weil and Sandler 1997). It can be used in the synthesis of aliphatic polyureas as well as for the production of alkyl carbonates and other organic compounds (Weil and Sandler 1997). It may also be used in the production of semiconductors (Chase et al. 2010). Refinery and fuel gases can contain carbonyl sulfide as an impurity. Combustion of sulfur-containing fuels can also result in the formation of carbonyl sulfide (EPA 1994d). Carbonyl sulfide has been used as a highly effective grain fumigant in place of the ozone-depleting methyl bromide (Bartholomaeus and Haritos 2005; NJDEP 2009; Wright 2000). In the same capacity, it can also be used in conjunction with phosphine gas to reduce insect resistance (Bartholomaeus and Haritos 2005).

5.4 DISPOSAL

Hydrogen Sulfide. Hydrogen sulfide is designated as a hazardous substance under Section 311(b) of the Clean Water Act (EPA 2009d). Disposal of wastes containing hydrogen sulfide is controlled by a number of federal regulations (see Chapter 8). The EPA-assigned hazardous waste number for hydrogen sulfide is U135 (EPA 2012b). Generators of waste exceeding 100 kg/month containing hydrogen sulfide must conform to the EPA regulations for the storage, transportation, treatment, and disposal of waste (EPA 2012f). Additional information concerning the accidental release of hydrogen sulfide and its reporting requirements is found in Chapter 8.

Carbonyl Sulfide. Carbonyl sulfide has been cited by the Department of Transportation (DOT), Department of Environmental Protection (DEP), Integrated Risk Information System (IRIS), National Fire Protection Association (NFPA), and EPA and is therefore on the New Jersey Right to Know Hazardous Substance List (NJDEP 2009). Carbonyl sulfide has an EPA hazardous waste number of D003, and therefore, those generating waste exceeding 100 kg/month must comply with EPA requirements (EPA 2012f).