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

5.1 PRODUCTION

Copper occurs naturally in many minerals, such as cuprite (Cu_2O), malachite ($CuCO3{\cdot}Cu(OH)_2$), azurite ($2CuCO_3{\cdot}Cu(OH)_2$), chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S), and bornite (Cu_5FeS_4). It also occurs uncombined as the metal (Tuddenham and Dougall 1979; Weast 1980). The copper content of ore deposits ranges from 0.5 to 5% by weight, whereas in igneous rock copper content ranges from 0.0005 to 0.011% (Duby 1980; Weant 1985). The three most important sources of copper are chalcocite, chalcopyrite, and malachite (Weant 1985). The major U.S. deposits are porphyry, indicating that they are of hydrothermal origin and are uniformly distributed in fractures or veins.

The United States is the world's second leading copper producer. The country produced 148 million metric tons of mined ore in 2001, with an average copper content of 0.48% (USGS 2001). Mine production of recoverable copper in the United States totaled 1,340,000 metric tons in 2001, an estimated 10% of world production behind Chile, which accounted for 35%. Copper was mined in six states in 2001, with Arizona accounting for 67% of U.S. copper production, followed by Utah (13%), New Mexico (13%) and Nevada (1%). There were 23 copper-producing mines in 2001, down from 27 in 2000. Thirteen of these are copper mines accounting for 99% of production in the United States. The remaining mines yielded copper as a by-product of gold, lead, silver, or zinc mining. Of the 13 largest mines, 10 were in Arizona, 2 were in New Mexico, and 1 was in Utah. Production, processing and use of copper and copper compounds in the United States, listed by state, are given in Tables 5-1 and 5-2, respectively.

After mining, most of the ore is crushed and concentrated to a material containing 15–35% copper using flotation. The remaining copper is obtained by first leaching the ore or tailings and then concentrating the leachate by applying solvent extraction or ion exchange (Butterman 1982).

Most primary copper is produced from its sulfide ore by matte smelting, an operation yielding a molten sulfide of copper and iron, called matte, which is further oxidized in a conversion step to yield metallic copper. The conversion operation takes place in two stages. In the first, slag-forming stage, FeS is oxidized to iron oxides, which combine with a silica flux to form a slag. In the second, copper-producing stage, CuS_2 is oxidized to form sulfur dioxide and metallic copper. The product of the conversion

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

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	10,000	99,999	12
AL	47	100	49,999,999	1, 2, 3, 5, 7, 8, 9, 11, 12, 13
AR	45	1,000	49,999,999	1, 2, 3, 4, 7, 8, 9, 12, 13, 14
AZ	26	0	999,999,999	1, 3, 4, 5, 7, 8, 9, 11, 12, 13, 14
CA	153	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
CO	14	1,000	499,999,999	2, 3, 4, 7, 8, 11, 12, 14
CT	54	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11
FL	28	1,000	9,999,999	2, 3, 4, 6, 7, 8, 9, 10, 11, 12
GA	58	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14
HI	2	1,000	9,999	12
IA	31	1,000	99,999,999	1, 2, 3, 4, 5, 7, 8, 9, 12
ID	3	10,000	999,999	1, 3, 8, 9, 12
IL	150	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14
IN	148	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	23	100	9,999,999	2, 3, 4, 6, 7, 8, 9, 11, 12, 14
KY	69	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
LA	10	100	9,999,999	2, 6, 8, 10, 12, 13, 14
MA	59	1,000	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12
MD	7	1,000	999,999	1, 2, 4, 5, 7, 8, 9
ME	10	10,000	9,999,999	2, 3, 8
MI	133	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12
MN	49	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	73	100	499,999,999	1, 2, 3, 4, 5, 7, 8, 9, 11, 12
MS	33	100	9,999,999	4, 7, 8, 9, 12
MT	1	1,000	9,999	6, 11
NC	72	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12
ND	2	10,000	99,999	7, 8
NE	18	1,000	9,999,999	1, 3, 5, 7, 8, 9, 11, 12, 13
NH	19	100	49,999,999	2, 3, 4, 7, 8, 9
NJ	36	1,000	49,999,999	1, 2, 3, 4, 6, 7, 8, 9, 11, 12
NM	7	1,000	9,999,999	2, 3, 8, 12
NV	6	1,000	99,999	7, 8, 11, 12
NY	100	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
OH	204	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	51	100	99,999,999	1, 2, 3, 4, 7, 8, 9, 11, 12, 13
OR	23	0	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12
PA	207	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
PR	22	1,000	9,999,999	1, 2, 3, 8, 11
RI	28	1,000	9,999,999	2, 3, 4, 6, 7, 8, 9, 12

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
SC	53	100	9,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14
SD	11	1,000	49,999,999	1, 5, 7, 8, 12, 14
TN	75	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
TX	102	100	99,999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14
UT	10	1,000	9,999,999	1, 3, 4, 5, 6, 7, 8, 11, 12
VA	42	1,000	9,999,999	1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 14
VT	4	1,000	99,999	2, 3, 4, 6, 8, 9
WA	24	1,000	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WI	148	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14
WV	12	1,000	9,999,999	2, 3, 6, 7, 8, 12
WY	4	0	99,999	1, 4, 9, 10, 12

Source: TRI01 2003

[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

Table 5-2. Facilities that Produce, Process, or Use Copper 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	5	10,000	9,999,999	1, 2, 3, 4, 5, 7, 10, 12, 13, 14
AL	37	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
AR	26	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
AZ	27	1,000	10,000,000,000	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
CA	74	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CO	7	100	99,999	1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
CT	24	1,000	999,999,999	1, 3, 5, 6, 7, 8, 9, 10, 11, 12
DC	1	1,000	9,999	12
DE	5	1,000	99,999	1, 2, 3, 5, 7, 9, 12, 13
FL	36	100	999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
GA	36	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
IA	26	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ID	8	1,000	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
IL	92	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
IN	72	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	11	0	999,999	1, 3, 5, 7, 8, 9, 10, 11, 12, 13
KY	39	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
LA	26	0	99,999,999	1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 13
MA	25	100	9,999,999	1, 3, 4, 5, 6, 7, 8, 10, 11, 12
MD	10	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13
ME	5	100	999,999	1, 3, 5, 7, 8, 11, 13
MI	52	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
MN	29	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	34	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MS	14	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13
MT	9	1,000	99,999,999	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14
NC	48	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ND	8	100	99,999	1, 5, 7, 9, 12, 13, 14
NE	10	10,000	99,999,999	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
NH	12	100	9,999,999	1, 3, 5, 6, 7, 8, 9, 11, 12, 13
NJ	24	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
NM	8	1,000	99,999,999	1, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13
NV	17	100	10,000,000,000	1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14
NY	30	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OH	83	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	14	100	999,999	1, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14
OR	16	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
PA	92	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PR	3	1,000	99,999	7, 10

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
RI	12	100	999,999	1, 2, 3, 4, 7, 8, 10, 12
SC	31	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
SD	2	1,000	999,999	1, 3, 5, 6, 10, 13
TN	47	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
TX	89	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	14	1,000	10,000,000,000	1, 3, 4, 5, 6, 7, 8, 9, 12, 13
VA	36	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WA	13	1,000	999,999	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
WI	35	0	999,999	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	17	1,000	999,999	1, 3, 4, 5, 7, 8, 9, 12, 13, 14
WY	4	100	999,999	1, 5, 9, 12, 13

Source: TRI01 2003

[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

operation is blister copper, which is 98.5–99.5% copper. Concentrated leachate from low-grade ore is subject to electrowinning, which electrolyzes aqueous sulfate solutions, or to cementation, which displaces copper from solution by a more active metal such as iron (Duby 1980). Further purification is obtained by electrolytic refining. For more details on copper mining, ore processing, smelting, and refining, see Duby (1980) and EPA (1980b).

Production of copper in the United States includes not only the processing of both domestic and foreign ores, but also the recovery of scrap. Scrap is a significant part of the U.S. copper supply. Scrap refers to both 'old scrap' (metal that has been used) and 'new scrap' (generated during fabrication). In 1999, smelting was performed in the United States by four primary smelters and two secondary smelters with a combined capacity of 1,750,000 metric tons per year (USGS 2000). Together, they produced 1,290,000 metric tons of copper from both domestic and foreign ores and scrap in 1999 (USGS 2001). In 2000, smelting was performed in the United States by four primary smelters and one secondary smelter with a combined capacity of 1,180,000 metric tons per year. Production of copper from U.S. smelters in 2000 was reported to be 1,000,000 metric tons, down from 1,290,000 metric tons in 1999 (USGS 2001). During 2000, 23 refineries operating with a combined capacity of 2,400,000 tons, produced 1,587,000 metric tons of copper from domestic and foreign ores. An additional 208,000 metric tons of copper was produced from new and old scrap for a combined total refinery production in the United States of 1,790,000 tons (USGS 2001). This level of refinery production was down from a level of 2,120,000 metric tons in 1999 (USGS 2001). Production of secondary copper and copper-alloys amounted to 1,490,000 metric tons in both 1999 and 2000 (USGS 2000). Apparent consumption for 2000 was 3,130,000 metric tons (USGS 2001). This includes domestic refined copper production, net imports of refined copper, copper recovered from old scrap, and stock adjustments. These alloys, primarily brass and bronze, contain approximately 60–>90% copper.

Most industrially important copper compounds are made starting with copper metal. Copper sulfate, the most commercially important copper compound, was produced by at least six companies in plants in Casa Grande, Arizona; Sewaren and Oak Bridge, New Jersey; El Paso and Garland, Texas; Sante Fe Springs, California; Union, Illinois; Copperhill, Tennessee; and Sumter, South Carolina (Jolly and Edelstein 1987).

Copper sulfate also is produced as a by-product of copper production by ore-leaching with sulfuric acid. Production of copper sulfate increased by 29% from 1996 to 2000, standing at 55,500 metric tons in 2000

(USGS 2000). However, in 2001, production of copper sulfate decreased slightly to 55,200 metric tons (USGS 2001). Recent production figures for other copper compounds were not located.

5.2 IMPORT/EXPORT

In 2000, 1,340,000 million tons of unmanufactured copper and 1,060,000 metric tons of refined copper were imported (USGS 2001). Peru, Canada, and Chile were the principal sources of imported refined copper. The quantity of imported unmanufactured copper increased by 93% since 1994; the increase was almost entirely in the importation of refined powder, as opposed to ore concentrate, blister copper, or scrap (USGS 1994, 2001). Imports of copper sulfate amounted to 4,650 metric tons and were primarily obtained from Australia and Mexico (USGS 2001).

In 2000, 483,000 metric tons of copper were exported, of which 19% was refined copper (USGS 2000). In 2001, exports dropped to 379,000 metric tons with a large decrease in exports of refined copper (from 93,600 metric tins in 2000 to 22,500 metric tons in 2001); exports of unalloyed copper scrap increased from 228,000 metric tons in 2000 to 262,000 metric tons in 2001 (USGS 2001).

5.3 USE

Copper is one of the most important metals because of its durability, ductility, malleability, and electrical and thermal conductivity. It is used primarily as the metal or in alloys. Its alloys, including brass, bronze, gun metal, and Monel metal, are important commodities. All current American coins are copper alloys. A small percentage of copper production goes into the manufacture of copper compounds, primarily copper sulfate.

The Copper Development Association's 2000 estimates of the end-use distribution of copper and copper-alloy products by the industrial sector were: construction, 39%; electrical and electrical products, 28%; transportation equipment, 11%; industrial machinery and equipment, 11%; and consumer and general products, 11% (USGS 2002). The top 10 markets for copper and copper-alloy during 1986 were, in order of importance: plumbing, building wire, telecommunications, power utilities, in-plant equipment, air conditioning, automotive electrical, automotive nonelectrical, business electronics, and industrial valves and fittings (Jolly and Edelstein 1987).

Copper sulfate was the only copper compound for which end-use distribution data were available; these data addressed only domestic producers. Sixty-five percent of production went into agricultural use, 28% for industrial uses such as metal finishing, mineral froth flotation and wood preservatives, and 7% for water treatment.

In agriculture, copper compounds are used as fungicides and to prepare copper fungicidal products, algicides for reservoirs and streams and nutritional supplements in animal feed and fertilizers. Industrial applications of copper sulfate include use as an activator in froth flotation of sulfide ores, production of chromated copper arsenate wood preservatives, electroplating, azo dye manufacture, mordant for textile dyes, petroleum refining and in the manufacture of other copper compounds such as copper hydroxide and copper carbonate (Mannsville Chemical Products 1984).

Copper compounds are applied as fungicides to foliage, seed, wood, fabric, and leather to protect against blight, downy mildew and rust. The 1982 consumption of copper-containing fungicides was 2.8 million pounds (Mannsville Chemical Products 1984). The major copper compound used for this purpose was the basic copper sulfate (1.8 million pounds). Other important fungicidal compounds were copper hydroxide, copper ammonium carbonate, copper oxychloride and copper oxychloride sulfate. The major target crops of copper-containing fungicides are citrus fruits, peanuts, deciduous fruits (other than apples), potatoes, vegetables and other field crops. Copper compounds are also used as algicides, insecticides and repellents. Products containing copper compounds frequently contain other chemicals and may be sold under various trade names. Formulation may be in wettable powders or aqueous solutions.

5.4 DISPOSAL

It is estimated that 60% of copper in scrap is recycled (Tuddenham and Dougall 1978). In 1986, ~40% of the copper produced came from this source (Jolly and Edelstein 1987). Copper-containing wastes can be concentrated using ion exchange, reverse osmosis, or evaporation, and then reclaimed by electrolysis (HSDB 2002). Copper and copper compounds not recycled are disposed of in landfills or released into waste water. Methods of copper containing sludge disposal from waste water treatment facilities include landfilling, landspreading, incineration or ocean disposal.

In case of a solid copper sulfate spill on land, the solids should be protected from rain and fire-fighting water by covering the material with plastic sheeting (HSDB 2002). In the event of a water spill, the copper sulfate should be neutralized with crushed limestone, slaked lime, or sodium bicarbonate, and the solidified masses should be removed.