RD422

PB89216212

SRC TR 81-626

SECOND DRAFT

Information Profiles on Potential Occupational Hazards: Copper and Compounds

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Contract No. 210-79-0030

March 1982

Prepared for:

National Institute for Occupational Safety and Health
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Rockville, Maryland 20857

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

(See ANSI-Z39.18)

TABLE OF CONTENTS

I. SCOPE OF DOCUMENT AND SUMMARY OF MAJOR FINDINGS

A. CLASS IDENTIFICATION

The copper compounds identified and considered are listed in the Appendix A. Both organic and inorganic copper compounds have been considered.

B. CHEMICALS TO BE ADDRESSED

Individual profiles have been prepared for the following copper compounds:

Copper metal
Copper(II) acetate
Copper(II) arsenate
Copper(II) carbonate, basic
Copper(I) chloride
Copper(II) chloride
Copper(I) cyanide
Copper(II) ethylhexanoate
Copper(II) hydroxide
Copper(II) 8-hydroxyquinolate
Copper(II) naphthenate
Copper(II) nitrate
Copper(II) oleate
Copper(I) oxide
Copper(II) oxide
Copper(II) sulfate
Copper(II) sulfide

Individual profiles were prepared for inorganic copper compounds identified as having an annual production of one million pounds or more and for organic copper compounds identified as having an annual production in excess of one-hundred thousand pounds.

It should be noted that production ranges available from the U.S. EPA (1980) are subject to limitations that may make those production ranges inaccurately low. For example, if a manufacturer claims confidential production, then his production range is not included in the EPA data. Also, a manufacturer can claim that his production volume, plant site, and plant name are confidential; therefore, nothing will appear on the EPA print-out of data. The available print-out may list three manufacturers when, in reality, there may be six or seven manufacturers for that particular compound.

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C. SUMMARY OF BIOLOGICAL ACTIVITY

Copper is an essential trace element and plays a specific physiologic role as a constituent of copper proteins, including cytochrome c oxidase and tryosinase. Major organs such as the liver, kidney, heart, brain, and pancreas, contain the highest concentrations while the intestinal tract, lung, spleen, muscle, skin and bone contain moderate to low concentrations.

Hypocupremia is a rare occurrence in humans because copper stores in a newborn's liver are in excess. However, numerous appearances of copper deficiency have been associated with severe hemolytic anemia, neutropenia and bone degeneration. Severe anemia has also been prevalent in ruminant and non-ruminant animals with hypocupremia. Patients with hepatolenticular degeneration (Wilson's Disease) are extremely deficient in the plasma protein, ceruloplasmin. This is responsible for toxic levels of copper being deposited in various tissues, especially the liver. An excessive accumulation of copper occurs around the cornea, causing Kayser-Fleischer rings which is pathognomonic for Wilson's disease.

Ingested copper is rapidly absorbed from the upper alimentary tract by an unknown mechanism. Absorbed copper, bound to serum albumin, is carried to the liver where it is stored and incorporated into cuproproteins. Ceruloplasmin transports copper from the liver to other tissues. Unabsorbed copper is excreted mainly via the biliary system. Minute amounts are excreted through sweat glands, Reversible effects include gastroenteritis, hemolytic anemia, and metal fume fever. Surveys of workers who have been exposed to copper fumes or dust have not exhibited any signs of chronic disease. Inhalation of dusts and mists does, however, cause irritation to the nasal mucosa and upper respiratory tract.

Histocytic granulomas in liver and lung tissue have been found in workers with Vineyard Sprayers Lung disease. Exposure of these workers to a copper sulfate spray (known as Bordeaux Mixture), used to prevent mildew on grapevines, ranged from 3 to 15 years. The condition of some patients improved considerably once exposure to the Bordeaux Mixture had ceased. Histopathological examination of tissue specimens taken from victims of copper poisoning have revealed renal tubular and hepatic necrosis, and intestinal epithelial degeneration.

The major findings of acute toxicity studies, in ruminant and non-ruminant animals, were systemic effects, especially gastrointestinal. LD_{50} values (140 mg/kg to 960 mg/kg for rats, oral administration; 2.86 mg/kg to 67 mg/kg for mice, intraperitoneal administration and 31 mg/kg orally in guinea pigs) have been determined for each of the copper salts in mammals. A number of subchronic studies revealed systemic effects (hemolytic anemia, hemoglobinuria, hemoglobinemia and jaundice) as the primary findings. Other observed effects included changes in weight gain (on diets high in copper) and micronodular lesions as well as some necrosis in the lungs, liver, and kidneys.

Evidence for the mutagenicity of copper has accumulated following studies with E. coli, MTK Sarcoma III tumor cells, Drosophila melanogaster, hamster embryo cells, calf thymus DNA and phage T4 DNA. Copper salts assayed for carcinogenicity in mammalian systems failed to show positive results. Two studies with Wistar Rats (intramuscular administration) and three studies on mice (two subcutaneous and one oral administration) revealed no oncogenic activity. Investigation of teratogenic effects for copper metal (copper loop intrauterine device implantation in rats and hamsters) were negative. However, intravenous administration of copper citrate and copper sulfate in hamsters caused malformations of the heart. Information on reproductive effects is rare, but one report revealed that copper metal prevented blastocyst development in rodents (following implantation of intrauterine loops and wires of copper).

II. DATA FOR COMMERCIALLY IMPORTANT CHEMICALS NOT INDIVIDUALLY PROFILED

Other copper compounds that have or may have some commercial importance are presented in Tables 1, 2, and 3; these compounds were not treated in individual profiles. Table 1 lists synonyms, CAS numbers, RTECS numbers, and chemical structures; Table 2 presents chemical and physical properties; Table 3 lists production volumes and uses, and summarizes manufacturing processes, and Table 4 lists manufacturers of copper compounds.

All copper chemicals considered for selection, regardless of their commercial importance, are listed in Appendix A.

Table 1. Copper Compounds

Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper(I) acetate Cuprous acetate Acetic acid, copper(1+)salt	598-54-9	---	CH_3COOCu
Copper(II) acetate, basic Cupric acetate, basic Copper subacetate Verdigris, blue, green	52503-63-6	---	$Cu(C_2H_3O_2)_2 \cdot CuO \cdot 6H_2O$ (variable)
Copper(II) acetoarsenite	12002-03-8		$3Cu(AsO_2)_2 \cdot Cu(C_2H_3COO)_2$
Paris green	1299-88-3	GL6475000	
Cupric acetoarsenite Schweinfurth green Copper acetate arsenite Emerald green ENT 884 French green Imperial green King's green Meadow green Mineral green Mitis green Moss green Ortho P-6 bait Parrot green Sowbug and cutworm bait Vienna green			
Copper(II) acetylacetonate Cupric acetylacetonate Copper 2,4-pentanedione Copper, bis(2,4-pentanedionato-O,O')-(SP-4-1)-	13395-16-9	---	$Cu(C_5H_7O_2)_2$

Table 1. Copper Compounds (Cont'd)

Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper(I) acetylide Cuprous acetylide	1117-94-8	---	$CuC\equiv CCu$
Copper(I) ammonium acetate Cuprous ammonium acetate Cuprous acetate, ammoniacal	43043-77-2	---	$CuNH_4(C_2H_3O_2)_2$
Copper(II) arsenite Cupric arsenite Cupric orthoarsenite Scheele's green Arsenious acid, copper(II) salt Acid copper arsenite Cupric green Scheele's mineral Swedish green	1302-97-2	CG3385000	$CuHAsO_3$ (variable)
Copper(I) bromide Cuprous bromide	7787-70-4	---	$CuBr$
Copper(II) bromide Cupric bromide	7789-45-9	---	$CuBr_2$
Copper chlorides, basic Basic copper chloride Colloidex Copper chloride hydroxide Copper oxychloride Coprantol Coxysan Cupramar Cupravit Cuprokylt Cuprosana Cuprovinol Cuprox Kautritil Viricuivre	1332-65-6 16004-08-3 12167-76-9 12356-86-4	GL7020000	$CuCl_2 \cdot 3Cu(OH)_2$ variable $CuCl_2 \cdot 2CuO \cdot 4H_2O$ variable Cu_2OCl_2 variable $Cu_4O_3Cl_2$ variable

Table 1. Copper Compounds (Cont'd)

Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper(II) chromate(III) Copper(II) dichromate Copper(II) chromite Cupric chromate Chromium copper oxide	12018-10-9	---	$CuCr_2O_4$
Copper(II) chromate(VI) Chromic acid, copper(2+) salt(1:1)	13548-42-0	---	$CuCrO_4$
Copper(II) chromate(VI), basic Cupric chromate, basic	1308-09-4	---	$CuCrO_4 \cdot 2CuO \cdot 2H_2O$
Copper(II) citrate 1,2,3-Propanetricarboxylic acid, 2-hydroxy-, copper(2+)salt(1:2) Cuprocitrol	866-82-0	GL7056000	$Cu_2C_6H_4O_7$
Copper(II) cyanide Cupric cyanide	4367-08-2	GL7175000	$Cu(CN)_2$
Copper(II) dimethyldithiocarbamate Cumate Compound-4018 Wolfen Carbamic acid, dimethyldithio-, copper(II) salt	137-29-1	FA0175000	$[(CH_3)_2NC(S)S]_2Cu$

Table 1. Copper Compounds (Cont'd)

Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper disodium ethylenediamine tetracetate Cuprate(2-),[[N,N'-1,2-ethanediylbis[N-(carboxymethyl)-glycinato]]-(4-)-N,N',O,O',O^{N},$O^{N'}$]-disodium	14025-15-1	---	$CuNa_2C_{10}H_{12}N_2O_8$
Copper ethylenediamine tetracetate Copper ethylenediamine tetracetic acid Copper EDTA Cuprate(2-), [[N,N'-1,2-ethanediylbis[N-(carboxymethylglycinato]]-(4-)-N,N',O,O',O^{N},O^{N}]-dihydrogen	54453-03-1	---	$CuH_2C_{10}H_{12}N_2O_8$
Copper(II) ferrocyanide Cupric ferrocyanide Cupric hexacyanoferrate (II) Hatchett's brown	13601-13-3	---	$Cu_2Fe(CN)_6 \cdot xH_2O$
Copper(II) fluoborate Cupric fluoborate Borate (1-), tetrafluoro-, copper (2+) salt	14735-84-3 38465-60-0	--- ---	$CuBF_4$ $BF_4 \cdot$ 1/2Cu
Copper(II) fluoride Cupric fluoride	7789-19-7	---	CuF_2 $CuF_2 \cdot 2H_2O$ (dihydrate)
Copper(II) formate Cupric formate	544-19-4	---	$Cu(CHO_2)_2$
Copper(II) gluconate Cupric gluconate	527-09-3	---	$Cu[CH_2OH(CHOH)_4CO_2]_2$

Table 1. Copper Compounds (Cont'd)

Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper(II) glycinate bis(glycinato)copper Cupric glycincate Cupric amino acetate Glycine copper complex Glycocoll-copper	13479-54-4	---	$Cu(H_2NCH_2COO)_2$
Copper(II) heptanoate Heptanoic acid, copper(2+)salt	5128-10-9	---	$Cu(C_7H_{14}O_2)_2$
Copper(I) iodide Cuprous iodide	7681-65-4	---	CuI
Copper(II) linoleate Cupric linoleate 9,12-Octadecadienoic acid (Z,Z)-, copper salt	7721-15-5	---	$C_{18}H_{32}O_2 \cdot xCu$
Copper(II) metaborate Cupric metaborate Copper borate	39290-85-2	---	$Cu(BO_2)_2$
Copper(II) neodecanoate Octanoic acid, 2,2-dimethyl- copper(2+) salt Neodecanoic acid, copper salt	32276-75-8 50315-14-5 68084-48-0	---	$Cu(C_{10}H_{20}O_2)_2$
Copper(II) orthophosphate Cupric phosphate trihydrate	10103-48-7	---	$Cu_3(PO_4)_2 \cdot 3H_2O$

Table 1. Copper Compounds (Cont'd)

Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper(II) oxalate Cupric oxalate Ethanedioic acid, copper (2+) salt	814-91-5	---	$CuC_2O_4 \cdot 1/2H_2O$
Copper(II) phosphate			
Phosphoric acid, copper(2+) salt(2:3)	7798-23-4	---	$Cu \cdot 2/3H_3O_4P$
Phosphoric acid, copper(2+) salt(2:1)	18718-12-2		
Copper(II) phthalocyanine Pigment blue 15 CI 74160 Cupric phthalocyanine	147-14-8	---	
Copper(I) potassium cyanide			
Cuprate(1-), bis(cyano-C)- potassium	13682-73-0	---	$CuK(CN)_2$
Cuprate(3-), tetrakis(cyano-C)-	14263-73-1	---	$CuK_3(CN)_4$
Copper(II) pyrophosphate Cupric pyrophosphate Diphosphoric acid, copper salt	10102-90-6	---	$Cu_2P_2O_7 \cdot 5H_2O$

Table 1. Copper Compounds (Cont'd)

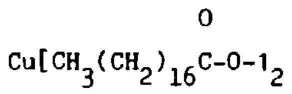
Compound and Synonyms	CAS Number	RTECS Number	Chemical Structure
Copper(II) resinate Cupric resinate	9007-39-0	---	variable
Copper(II) stearate Cupric stearate Octadecanoic acid, copper (2+) salt	660-60-6	---	 $Cu[CH_3(CH_2)_{16}\overset{O}{\overset{\Vert}{C}}\text{-}O\text{-}]_2$
Copper(II) sulfate, basic Basic cupric sulfate Copper hydroxide sulfate Cupric subsulfate Basi-cop Bordeaux mixture Langite	1332-14-5	GL8930000	$CuSO_4\cdot 3Cu(OH)_2\cdot H_2O$
Copper(I) sulfide Cuprous sulfide Chalcocite Copper glance	22205-45-4	---	Cu_2S
Copper(II) tallate Cupric tallate Tall oil, cupric salt	61789-22-8	---	variable
Copper(I) thiocyanate Cuprous thiocyanate Copper sulfocyanide	1111-67-7	---	CuSCN
Copper(II) 3,5,5-trimethylhexanoate Hexanoic acid, 3,3,5-trimethyl-, copper(2+) salts	35206-70-3	---	$Cu(C_9H_{18}O_2)_2$

Table 2. Copper Compounds: Chemical and Physical Properties[a]

Compound	Description	Boiling Point (°C)	Melting Point (°C)	Vapor Pressure	Solubility (g/100 g)	Specific Gravity	Molecular Weight
Copper(I) acetate	white to transparent crystals	--	decomp.	--	decomp.	--	122.6
Copper(II) acetate, basic	green to blue solid depending upon formula	--	--	--	sl. sol.	--	369.26
Copper(II) acetoarsenite	emerald green powder	--	--	--	insol.	--	1013.71
Copper(II) acetylacetonate	crystalline powder	sublimes	>230	--	sl. sol.	--	261.76
Copper(I) acetylide	red powder	--	decomp.	--	very sl. sol.	--	151.10
Copper(I) ammonium acetate	--	--	--	--	--	--	--
Copper ammonium carbonate	--	--	--	--	--	--	--
Copper(II) arsenite	light green powder	--	decomp.	--	insol.	--	187.46
Copper(II) bromide	black, deliquescent crystalline powder or crystals	900	498	--	very sol.	4.77	223.31
Copper(I) bromide	white powder or cubic crystals	1345	504	--	sl. sol.	4.72-4.98	143.46
Copper chlorides, basic	green-blue or yellow powder	--	--	--	insol.	--	variable
Copper(II) chromate(III)	grayish-black to blue-black crystals	--	decomp.	--	insol.	--	231.56
Copper(II) chromate(VI)	reddish-brown crystals	--	decomp.	--	insol.	--	179.55
Copper(II) chromate(VI), basic	light chocolate-brown powder	--	decomp.	--	insol.	--	374.64
Copper(II) citrate	green or bluish-green crystals or powder	--	decomp.	--	slight	--	315.18
Copper(II) cyanide	green powder	--	decomp.	--	insol.	--	115.58
Copper(II) dimethyldithiocarbamate	dark brown powder	--	>325	--	insol.	5.25	303.98

Table 2. Copper Compounds: Chemical ad Physical Properties (Cont'd)

Compound	Description	Boiling Point (°C)	Melting Point (°C)	Vapor Pressure	Solubility^c (g/100 g)	Specific Gravity	Molecular Weight
Copper disodium ethylenediamine tetracetate	---	--	--	--	--	--	397.71
Copper ethylene diamine tetracetate	---	--	--	--	--	--	353.75
Copper(II) heptanoate	---	--	--	--	--	--	323.90
Copper(II) ferrocyanide	reddish-brown powder	--	--	--	insol.	--	339.04 (anhydride)
Copper(II) fluoborate	--	--	--	--	--	--	--
Copper(II) fluoride	anhydride - white crystals dihydrate - blue crystals	- --	950 decomp. decomp.	-- --	4.7 4.7	4.23 2.93	101.54 137.57
Copper(II) formate	blue crystals	--	--	--	12.5	1.831	153.55 (anhydride)
Copper(II) gluconate	light blue to bluish-green powder	--	--	--	30 (at 25°C)	--	453.58
Copper(II) glycinate	white (anhydride) to blue (hydrates) crystals	--	--	--	sol.	--	211.66 (anhydride)
Copper(I) iodide	pure white to brownish-yellow powder	1290	606	--	0.0008 (at 18°C)	5.62	190.46
Copper(II) linoleate	--	--	--	--	--	--	--
Copper(II) metaborate	bluish-green crystalline powder	--	--	--	sl. insol.	3.859	149.16
Copper(II) neodecanoate	solid	--	--	--	--	--	267.79
Copper(II) orthophosphate	light blue powder	--	decomp.	--	insol.	--	434.61
Copper(II) oxalate	blue-white powder	--	decomp.	--	0.00253 (at 25°C)	--	160.57
Copper(II) phosphate	solid	--	--	--	--	--	267.79

Table 2. Copper Compounds: Chemical and Physical Properties (Cont'd)

Compound	Description	Boiling Point (°C)	Melting Point (°C)	Vapor Pressure	Solubility[c] (g/100 g)	Specific Gravity	Molecular Weight
Copper(II) phthalocyanine	blue-red crystalline	--	--	-	--	--	576.08
Copper(II) potassium cyanide	solid	--	--	--	--	--	154.68 or 284.92
Copper(II) pyrophosphate	--	--	--	--	--	--	391.1
Copper(II) resinate	green powder	--	--	--	insol.	--	--
Copper(II) stearate	light blue, amorphous powder	--	125-250	--	insol.	--	630.50
Copper(II) sulfate, basic	fine, light-blue, gelatinous powder	--	decomp.	--	insol.	3.78	470.30
Copper(I) sulfide	bluish to grayish-black lustrous powder	--	1100	--	insol.	5.6	159.15
Copper(II) tallate	--	--	--	--	--	--	--
Copper(I) thiocyanate	yellow-white, amorphous powder	--	1084	--	0.0005 (at 18°C)	2.85	121.62
Copper(II) 3,5,5-trimethylhexanoate	solid	--	--	--	--	--	380.01

[a] "--" = information not readily available.
[b] decomp. = decomposes.
[c] sl. sol. = slightly soluble; insol. = insoluble; very sol. = very soluble; sol. = soluble; sl. insol. = slightly insoluble.

Table 3. Production Volume, Uses, and Manufacturing Processes of Various Copper Compounds

Compound	Production	Uses	Manufacturing Processes
Copper(I) acetate	Not available	To absorb olefins, to separate γ-globulins, and as a catalyst in the oxidation of phenols to poly(phenylene ethers) and diphenoquinones in the presence of tertiary amines (Kust, 1979)	By the slow addition of a solution of hydroxylamine hydrogen sulfate to a hot mixture of ammonical copper(II) acetate solution buffered by a large amount of ammonium acetate (Kust, 1979). See Figure 2.
Copper(II) acetate, basic	not available, but much less than copper(II) acetate	Major uses--pigments in water- and oil-based paints. Other uses--fungicide; mold preservative; textile mordant; and catalytic preparations (Kust, 1979; Lawler, 1977; Winter et al., 1965; Utter and Tuwiner, 1949).	Neutralization of acetic acid solutions of copper(II) acetate (Kust, 1979).
Copper(II) acetoarsenite	1948: 1 million lb (Frear, 1951) 1979: 10-100 thousand lb (SRC estimate)	Insecticide; wood preservative; paint pigment (Kust, 1979); and pyrotechnics (Lancaster et al., 1972).	Reaction of solutions of cupric sulfate or chloride with Na$_2$CO$_3$ and arsenous acid forming a cupric arsenite precipitate which is reacted with acetic acid (Winter et al., 1965) See Figure 2.
Copper(II) acetylacetonate	1977: >1 thousand lb (U.S. EPA, 1980)	To regulate polymerization reactions; chelating compound; catalyst; and lubricant additive (various patent data).	Not available
Copper(I) acetylide	Not available	As a catalyst in the manufacturing of 2-propyn-1-ol and acrylonitrile; in promoting the reaction of acetylene with formaldehyde; as an intermediate in preparation of pure copper powder (Kust, 1979).	Reaction of ammonical solutions of Cu(I) with acetylene followed by drying (Kust, 1979).
Copper(I) ammonium acetate	1977: >1 thousand lb	Used in a method for removing residual carbon monoxide that is left after production of a CO product; it is used as a scrubber solution which washes the monoxide gas and chemically converts it (Bartish and Drissel, 1978; Frear and Baber, 1963).	Not available

Table 3. Production Volume, Uses, and Manufacturing Processes of Various Copper Compounds

Compound	Production	Uses	Manufacturing Processes
Copper(II) arsenite	Not available	Pigment; intestinal antiseptic in medicine; wood preservative; insecticide; fungicide, and rodenticide (Winter et al., 1965).	Precipitation reaction using $CuSO_4$ with appropriate arsenites or Cu metal and boiling NH_4Cl solution (Winter et al., 1965). See Figure 2.
Copper(II) bromide	Not available	Brominating agent; intensifier in photography; wood preservative; batteries; stabilizer for acrylated polyformaldehyde; catalyst; cutting solution ingredient for machining steel; humidity indicator; extraction of sulfur from oil and removing lead from gasoline (Winter et al., 1965; Kust, 1979).	Dissolving CuO in hydrobromic acid and evaporating over sulfuric acid (Winter et al., 1965; Kust, 1979).
Copper(I) bromide	Not available	Catalyst in the oxidative polymerization of xylenol; accelerator in vulcanization of butyl rubber resins; photographic emulsions (Kust, 1979).	Reduction of $CuSO_4$ solution containing KBr with SO_2 or other standard reducing agents, or with metallic copper (Kust, 1979).
Copper chlorides, basic	Production not available 1977 import: >100 thousand lb (U.S. EPA, 1980)	Agricultural fungicide; wood preservatives; electronics; metallurgy, and catalysts (Ayers and Johnson, 1976; Winter et al., 1965; Kust, 1979).	Precipitation reactions at controlled pH (Kust, 1979). See Figure 2: (1) cupric chloride with cupric hydroxide (2) HCl with cupric hydroxide (3) Air oxidation of cuprous chloride (Winter et al., 1965)
Copper(II) chromate(III)	1977: >122 thousand lb (U.S. EPA)	Mordant in textiles dyeing; to catalyze ammonia oxidation; detergent manufacturing; hydrogenation; oxidation of exhaust gases in pollution control; burning of solid fuel propellents (Kust, 1979).	Heating copper(II) chromate(VI) above 400°C (Kust, 1979).
Copper(II) chromate(VI)	1977: 10-100 thousand lb (U.S. EPA, 1980)	As a fungicide, in electrolytic treatment of metals, in waterproofing textiles, in epoxy adhesives, and as a wood preservative (Kust, 1979)	(1) Heating copper(II) oxide and chromium(VI) oxide (Kust, 1979) (2) Heating copper hydroxide and potassium dichromate solution (Winter et al., 1965)

Table 3. Production Volume, Uses, and Manufacturing Processes of Various Copper Compounds (Cont'd)

Compound	Production	Uses	Manufacturing Processes
Copper(II) chromate(VI), basic	1977: 1-10 thousand lb (U.S. EPA, 1980)	Mordant in dyeing; wood preservative (Hawley, 1977)	Precipitation of a neutral solution of copper(II) chromate(VI) (Kust, 1979)
Copper(II) citrate	1977: 1-10 thousand lb (U.S. EPA, 1980) less than 10 thousand lb annually (Trotz and Pitts, 1981)	Swimming pool algicide (Trotz and Pitts, 1981); astringent, antiseptic (The Merck Index, 1976).	Precipitation reaction of hot solutions of $CuSO_4$ and sodium citrate (The Merck Index, 1976); See Figure 2
Copper(II) cyanide	Not available	Electroplating copper to iron (Lawler, 1977).	Precipitation of copper sulfate and potassium cyanide solutions (Winter et al., 1965). See Figure 2.
Copper(II) dimethyldithiocarbamate	Not available	Primary rubber accelerator in SBR; as a secondary accelerator with thiazoles; and in butyl rubber for molded and extruded goods (Hawley, 1977).	Not available--but possibly from dithiocarbamic acid with copper salts.
Copper disodium ethylenediamine tetracetate	1977: >10 thousand lb (U.S. EPA, 1980)	Not available	Not available
Copper ethylenediamine tetracetate	less than 10 thousand lb annually (Trotz and Pitts, 1981)	Swimming pool algicide (Trotz and Pitts, 1981)	Not available
Copper(II) ferrocyanide	Not available	Paint and enamel pigment; photographic toning; osmotic membranes (Lawler, 1977; The Merck Index, 1976).	Copper salt solution plus potassium ferrocyanide (The Merck Index, 1976). See Figure 2.
Copper(II) fluoborate	1977: >2 thousand lb (U.S. EPA, 1980)	Electroplating; catalyst for epoxy resins; electrically conducting coatings; wood preservative (Kust, 1979).	Neutralizing fluoroboric acid with copper carbonate or hydroxide and concentrating solution to achieve crystallization (Kust, 1979).

Table 3. Production Volume, Uses, and Manufacturing Processes of Various Copper Compounds (Cont'd)

Compound	Production	Uses	Manufacturing Processes
Copper(II) fluoride	Not available	Construction of cathodes in nonaqueous galvanic cells; flux in casting gray iron (White, 1966); enamels and ceramics (Lawler, 1977).	Hydrofluoric acid and basic copper carbonate (White, 1966). See Figure 1.
Copper(II) formate	1977: >1 thousand lb (U.S. EPA, 1980)	Antibacterial agent in cellulose treatment (Winter et al., 1965).	Dissolving copper oxide, hydroxide, or carbonate in formic acid (Winter et al., 1965).
Copper(II) gluconate	Not available Sold commercially in 24 lb drums	Treatment of arthritis; breath freshener; dietary copper supplement (Kust, 1979; The Merck Index, 1976).	Reaction of gluconic acid with basic copper carbonate (Kust, 1979).
Copper(II) glycinate	Not available	Catalyst for rapid biochemical assimilation of iron; electroplating baths; photometric analysis of copper (Hawley, 1977; The Merck Index, 1976).	Glycine plus a copper salt (The Merck Index, 1976).
Copper(II) heptanoate	1977: 10-100 thousand lb (U.S. EPA, 1980)	Not available--but possibly the same as other copper soaps	See Figure 3.
Copper(I) iodide	1965: 10 thousand lb (USTC, 1966)	Photographic emulsions and transport films; catalysts; ice nucleating in cloud seeding; cathode-ray tube coatings (Kust, 1979; Winter et al., 1965).	Precipitation of $CuSO_4$, KI, and sodium thiosulfate (Kust, 1979). See Figure 2.
Copper(II) linoleate	<100 thousand lb annually (SRC estimate)	Metallic paint driers and printing inks (Bradley, 1975).	Linolaic acid with copper salts. See Figure 3.
Copper(II) metaborate	Not available	Fireproofing agent for wood; oil and ceramic pigment; insecticide for wheatrust compounds (Lawler, 1977; Hawley, 1977).	Interaction of copper hydroxide and boric acid (Hawley, 1977).

Table 3. Production Volume, Uses, and Manufacturing Processes of Various Copper Compounds (Cont'd)

Compound	Production	Uses	Manufacturing Processes
Copper(II) neodecanoate	Not available	Not available--but possibly the same as other copper soaps.	See Figure 3
Copper(II) ortho phosphate	Not available	Fungicides; medicines; feed additive; catalyst; fertilizers; emulsions; corrosion inhibitor for phosphoric acid; protectant for metal surfaces against oxidation (Lawler, 1977; The Merck Index, 1976).	Occurs naturally. Synthetic method not available.
Copper(II) oxalate	Not available	Catalyst; stabilizer for acetylated polyformaldehyde; anticaries compositions; seed treatment to repell birds and rodents (The Merck Index 1976).	Reaction of $CuSO_4$ with oxalic acid (The Merck Index, 1971). See Figure 1.
Copper(II) phosphate	1977: >2 thousand lb (U.S. EPA, 1980)	Catalysts; fungicides; insecticides (Winter et al., 1965; VanWazer, 1968)	Not available
Copper(II) phthalocyanides	1978: 14.751 million lb (USITC, 1978) 1977: 2.44-24.4 million lb (import) (U.S. EPA, 1980)	Dyes and pigments (Moser, 1968).	Heating phthalic anhydride, urea, $CuSO_4$, and catalyst (Moser, 1968; Steadman et al., 1977). See Figure 4.
Copper(II) potassium cyanide	1977: >300 thousand lb (U.S. EPA, 1980)	In electroplating and electrocatalysts	Not available
Copper(II) pyrophosphate	Not available	Corrosion inhibitor for phosphoric acid; protectant of metal surfaces against oxidation; fungicide; catalysts; fertilizers (Winter et al., 1965).	Double decomposition of sodium pyrophosphate with a copper salt (Winter et al., 1965).

Table 3. Production Volume, Uses, and Manufacturing Processes of Various Copper Compounds (Cont'd)

Compound	Production	Uses	Manufacturing Processes
Copper(II) resinate	1977: 1-10 thousand lb (U.S. EPA, 1980)	Antifouling agent in paints; soap drier; insecticides (Hawley, 1977)	Heating $CuSO_4$ and resin oil and filtering and drying the precipitate (Hawley, 1977). See Figure 2.
Copper(II) stearate	1977: 1-10 thousand lb (U.S. EPA, 1980)	Coatings for xerographic plates and heat-sensitive coatings for photoduplication; color stabilizer in metal dyes; catalysts (Kust, 1979); paint drier; textile and wood preservatives; bronzing of plaster statues (Hawley, 1971; <u>The Merck Index</u>, 1976).	Interaction of $CuSO_4$ and sodium stearate (Hawley, 1977). See Figure 3.
Copper(II) sulfate, basic	1977: >0.122 million lb (U.S. EPA, 1980)	Fungus control of vegetables and fruits (Winter <u>et</u> <u>al</u>., 1965).	Ammoniating $CuSO_4$ solution to precipitation (Winter <u>et</u> <u>al</u>., 1965). See Figure 2.
Copper(I) sulfide	1977: 0.21-2.1 billion lb (natural ore) (U.S. EPA, 1980)	Commercially important ore as source of copper. Limited uses in paints, lubricants, and catalysts (Winter <u>et</u> <u>al</u>., 1965).	Mined
Copper(II) tallate	1973: 66 thousand lb (USITC, 1975)	Paint drier (Bradley, 1975) and cordage preservative (Turner, 1966).	Precipitation of $CuSO_4$ and tall oil. See Figure 2.
Copper(I) thiocyanate	1977: 2-20 thousand lb (U.S. EPA, 1980)	Marine antifouling paints; explosive primers; textile printing; intermediate (Hawley, 1977; <u>The Merck Index</u>, 1976).	Not available
Copper(II) 3,5,5-trimethylhexanoate	1977: 30-300 thousand lb (U.S. EPA, 1980)	Not available--but possibly the same as other copper soaps	See Figure 3

Table 4. Copper Compounds--Manufacturers
(SRI International, 1980; U.S. EPA, 1980)

Compound	Manufacturer (Location)
Copper(I) acetate	Copolymer Rubber and Chem. (Baton Rouge, LA)
Copper(II) acetate, basic	---
Copper(II) acetoarsenite	Los Angeles Chem. Co. (South Gate, CA)
Copper(II) acetylacetonate	Mackenzie Chem. Wks (Bush, LA) Mooney Chem. (Franklin, PA) The Shepherd Chem. (Cincinnati, OH)
Copper(I) acetylide	---
Copper(I) ammonium acetate	Mineral Research and Dev. (Concord, NC) Dow Chem. (Freeport, TX) Firestone Syr. Rub and Latex (Orange, TX)
Copper(II) arsenite	---
Copper(II) bromide	Eastman Kodak (Rochester, NY) St. Louis Plant (St. Louis, MO)
Copper(I) bromide	Eastern-Guardian Chem. (Hauppauge, NY) Eastman Kodak (Rochester, NY) Cooper Chem. (Long Valley, NJ)
Copper chlorides, basic	Imperial West Chem. (Antioch, CA) American Chemet Corp. (East Helena, MT) CP Chem. (Sewaren, NJ)
Copper(II) chromate(III)	Mineral Research and Dev. (Concord, NC) Dow Chem. (Ludington, MI) Calsicat Div. (Erie, PA) United Catalysts (Louisville, KY) The Shepherd Chem. (Cincinnati, OH) The Harshaw Chem. (Elyria, OH)

Table 4. Copper Compounds--Manufacturers
SRI International, 1980; U.S. EPA, 1980)

Compound	Manufacturer (Location)
Copper(II) chromate(VI)	Dow Chem. (Ludington, MI)
Copper(II) chromate(VI), basic	United Catalysts (Louisville, KY)
Copper(II) citrate	Alpine Lab. (Bay Minette, AL)
Copper(II) cyanide	C.P. Chem. (Sewaren, NJ) DuPont (Niagara Falls, NY)
Copper(II) dimethyldiethiocarbamate	Vanderbilt Chem. (Bethel, CT)
Copper disodium ethylenediamine tetracetate	Eastman Kodak (Rochester, NY) Technie Inc. (Cranston, RI) Ciba-Geigy (McIntosh, AL) WR Grace and Co. (Nashua, NH)
Copper ethylenediamine tetracetate	Technic Inc. (Cranston, RI)
Copper(II) ferrocyanide	---
Copper(II) fluoborate	Allied Chem. (Marcus Hook, PA) C.P. Chem (Sewaren, PA) Harshaw Chem. (Cleveland, OH) Harstan Chem. (Brooklyn, NY) Fidelity Chem. (Newark, NJ)
Copper(II) fluoride	Pennwalt (Tulsa, OK)
Copper(II) formate	Kocide Chem. (Houston, TX) Auralux Corp. (Hope Valley, RI) The Shepherd Chem. (Cincinnati, OH)
Copper(II) gluconate	Pfizer Inc. (Brooklyn, NY)
Copper(II) glycinate	---
Copper(II) heptanoate	Tenneco (Elizabeth, NJ)
Copper(I) iodide	Ajay Chem. (Powder Springs, GA) Chemetals Corp. (Curtis Bay, MD) Deepwater Chem. (Irvine, CA) Kocide Chem. (Houston, TX) The Shepherd Chem. (Cincinnati, OH) Tuscarora Chem. (Chittenango, NY) Eastman Kodak (Rochester, NY) Copper Chem. (Long Valley, NJ) Arista Lab. (Cincinnati, OH)

Table 4. Copper Compounds--Manufacturers
SRI International, 1980; U.S. EPA, 1980) (Cont'd)

Compound	Manufacturer (Location)
Copper(II) linoleate	Troy Chem. (Newark, NJ)
Copper(II) metaborate	Humphrey Chem. (Edgewood Area, MD)
	Texas Instruments (Attleboro, MA)
Copper(II) neodecanoate	Mooney Chem. (Franklin, PA)
	Tenneco (Elizabeth, NJ)
	The Shepherd Chem. (Cincinnati, OH)
Copper(II) orthophosphate	U.C.C. Site No. 02-305 (Ambler, PA)
	Union Carbide (St. Joseph, MO)
	U.C.C. Site No. 02-302 (Ferndale, MI)
	C.P. Chem. (Sewaren, NJ)
Copper(II) oxalate	The Shepherd Chem. (Cincinnati, OH)
Copper(II) phosphate	C.P. Chem. (Sewaren, NJ)
	Mobil Chem. (Charleston, TN)
	(Ferndald, OH)
Copper(II) phthalocyanine	Industrial Color (Joliet, IL)
	Joliet Colors (Joliet, IL)
	Phthalchem (Cincinnati, OH)
	Eastman Kodak (Rochester, NY)
	The Gillette Co. (N. Chicago, IL)
	H. Kohnstamm and Co. (Camden, NJ)
	Borden Printing Inks (Cincinnati, OH)
	American Cyanamid (Bound Brook, NJ)
	BASF Wyandotte (Kearney, NJ)
	Bostik South (Greenville, SC)
	Thomasett Color (Newark, NJ)
	Hercules (Glen Falls, NY)
	Hilton-Davis Chem. (Cincinnati, OH)
	Ridgway Color and Chem. (Ridgway, PA)
	Chemetron Pigments (Holland, MI)
	(Hungtington, WV)
	DuPont (Wilmington, DE)

Table 4. Copper Compounds--Manufacturers
SRI International, 1980; U.S. EPA, 1980) (Cont'd)

Compound	Manufacturer (Location)
Copper(I) potassium cyanide	Fidelity Chem. (Newark, NJ) DuPont (Niagara Falls, NY) Harstan Chem. (Brooklyn, NY)
Copper(II) pyrophosphate	C.P. Chem. (Sewaren, NJ) M and T Chem. (East Chicago, IN) Harstan Chem. (Brooklyn, NY)
Copper(II) resinate	Kocide Chem. (Houston, TX) California Resin and Chem. (Vallejo, CA) Englehard Ind. (East Newark, NJ)
Copper(II) stearate	Norac-Mathe Div. (Lodi, NJ)
Copper(II) sulfate, basic	Cities Services (Copperhill, TN) C.P. Chem. (Sewaren, NJ) Kocide Chem. (Houston, TX) Phelps Dodge (Maspeth, NY) Leffingwell Chem. (Brea, CA) ABC Compounding (Atlanta, GA) Cities Services (Seymour, CT) C.P. Chem. (Powder Springs, GA)
Copper(I) sulfide	SCM-Glidden (Hammond, IN) Chino Mines (Hurley, NM) Utah Copper (Salt Lake City, UT) Nevada Mines (McGill, NV) Ray Mines Div. (Haychem, AZ)
Copper(II) tallate	Troy Chem. (Newark, NJ) Cities Services (Copperhill, TN) Tower Chem. (Clermont, FLO C.P. Chem. (Powder Springs, GA)
Copper(I) thiocyanate	The Shepherd Chem. (Cincinnati, OH) Ionac Chen. (Birmingham, NJ)
Copper(II) 3,5,5-trimethylhexanoate	Tenneco Chem. (Elizabeth, NJ) (Long Beach, CA)

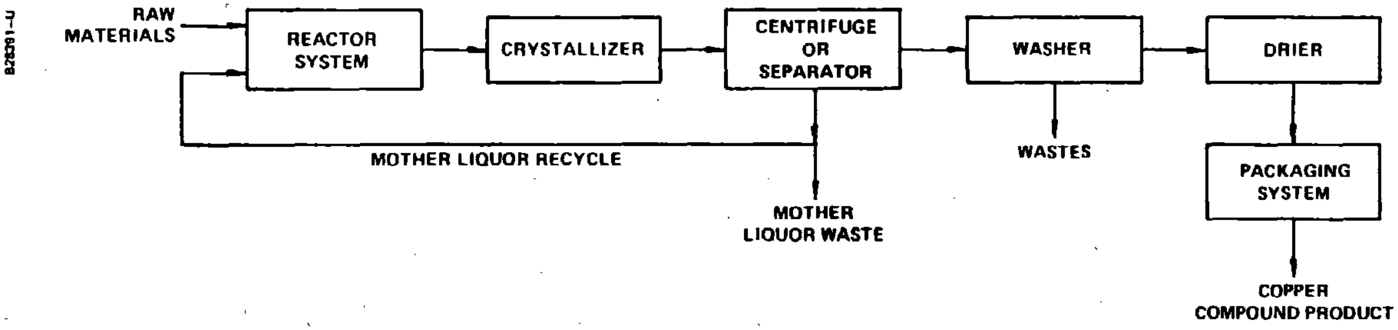


Figure 1. Copper Compound Production Via Crystallization

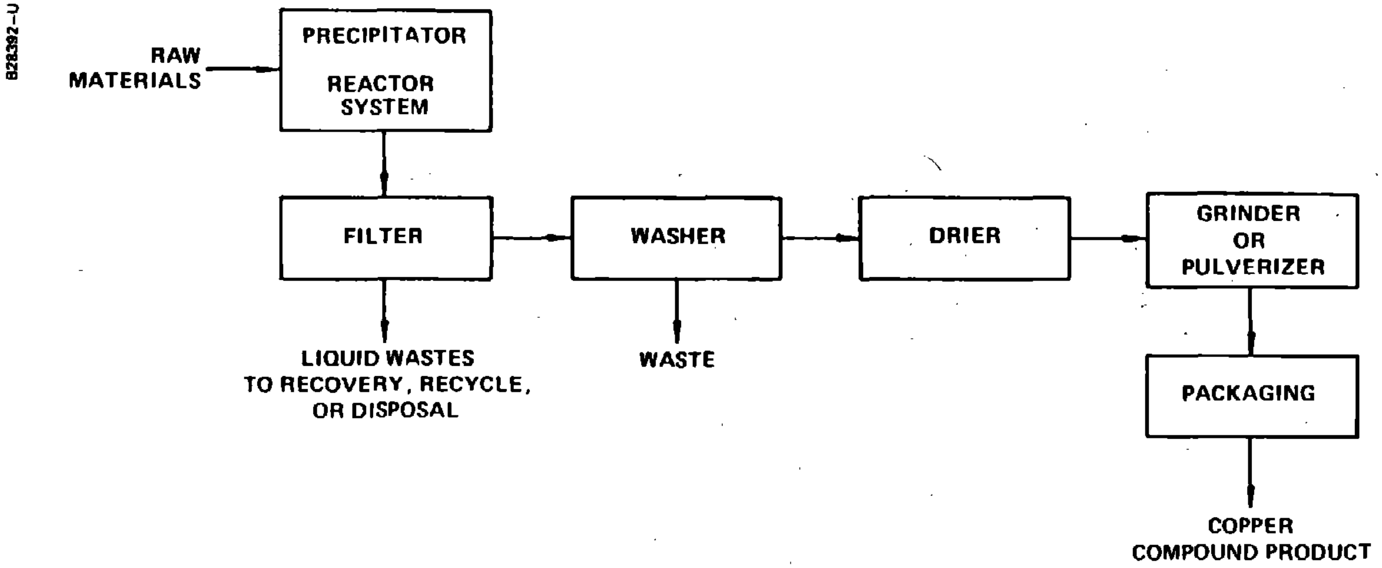


Figure 2. Copper Compound Production Via Precipitation

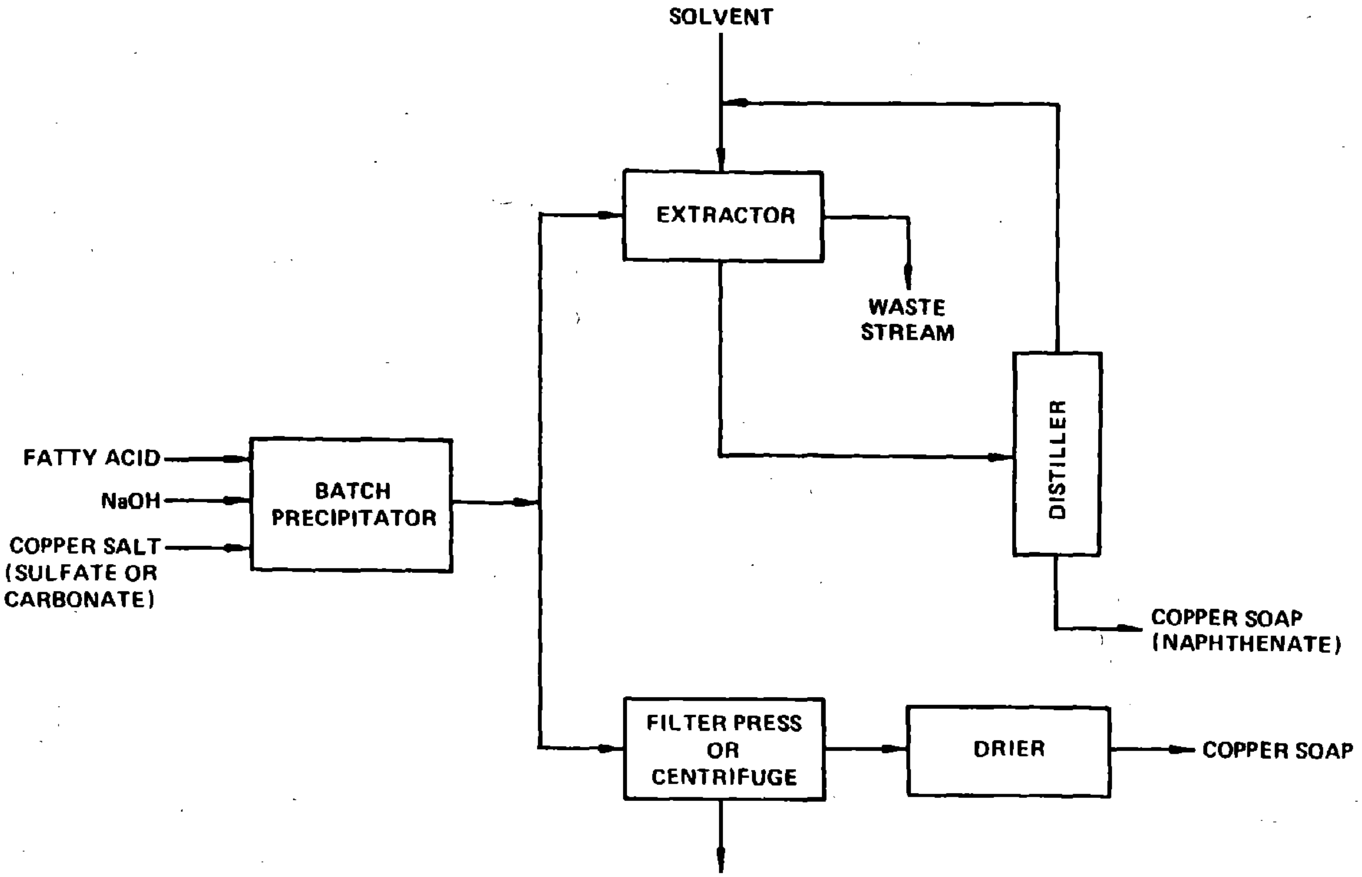


Figure 3. Manufacture of Copper Soaps

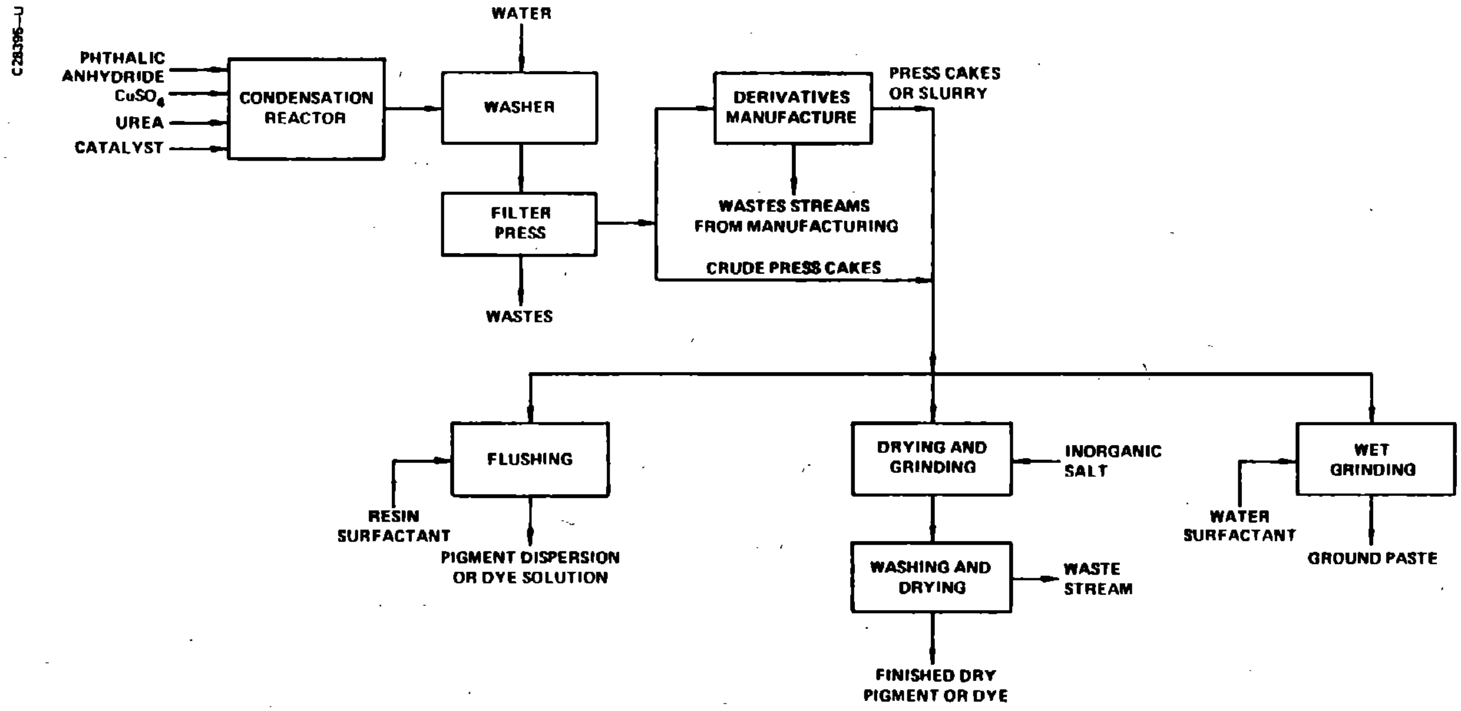


Figure 4. Manufacture of Copper Phthalocyanine Dyes (Adapted from Steadman et al., 1977; Moser, 1968.)

III. INFORMATION PROFILES

A. COPPER

1. Chemical Name: Copper

2. Chemical Structure: Cu

3. Synonyms: C.I. 77400
   C.I. Pigment Metal 2

4. Chemical Abstracts Service (CAS) Number: 7440-50-8

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   GL5325000

6. Chemical and Physical Properties:

Description:	reddish, lustrous, ductile, malleable metal; in the form of ingots, sheets, wires, bars, or powders
Molecular Weight:	63.54
Boiling Point:	2595°C
Melting Point:	1083°C
Vapor Pressure:	---
Solubility:	insoluble in water; soluble in nitric acid; very slightly soluble in HCl and NH_4OH
Specific Gravity:	8.92
Stability:	Noncombustible except as a powder

7. Production

Production figures for copper metal are listed below. Annual growth is projected at an average of 3.5% through the year 2000 (Bureau of Mines, 1979).

The following production data are available for copper (Bureau of Mines, 1979; Tuddenham and Dougall, 1979).

Year	Production (in Thousands of Short Tons)
1978	1597
1976	1607
1974	1594
1972	1662
1969	1542
1965	1350

8. Use

Copper metal was used in the following applications in the United States in 1976 (Tuddenham and Dougall, 1979):

End-Use	Consumption, Thousands of Short Tons	Percent
Electrical	1158	53.8
Construction	332	15.4
Machinery	289	13.4
Transportation	230	10.7
Ordnance	35	1.6
Other	108	5.0
	2152	

In the tabulation above, ordnance use includes copper items used for shell casings, projectile fuses and rotating bands, and fire-control equipment. Miscellaneous uses include chemicals and inorganic pigments and making of coins, various precision instruments, and a variety of decorative items.

Consumption figures for refined copper in 1976 are also available from the U.S. EPA (1978):

Consumer	Consumption, Thousands of Short Tons
Wire mills	1343
Brass mills	574
Secondary smelters	3
Chemical plants, foundries, and miscellaneous plants	36

9. Manufacturers and Distributors

Most copper production is now being accomplished with conventional smelting/refining operations based on the reverberatory furnace. The operations occur in about 25 locations, all but five of which were operating before World War II (U.S. EPA, 1978). These primary copper producers are listed in Table 5.

At six other installations, newer technology has been or is now operating; however, these installations do not account for a sizeable percentage

Table 5. U.S. Primary Copper Producers (U.S. EPA, 1978)
(Conventional Smelting/Refining Operations)

Company	Location	Description	Capacity, metric ton/year (Cu content)
AMAX, Inc	Carteret, NJ	Refinery	236,000
The Anaconda Company	Anaconda, MT	Smelter	180,000
	Great Falls, MT	Refinery	229,000
ASARCO, Inc.	Tacoma, WA	Smelter/refinery	91,000/142,000
	El Paso, TX	Smelter	104,000
	Hayden, AZ	Smelter	163,000
	Amarillo, TX	Refinery	381,000
Cerro Corporation	St. Louis, MO	Refinery	236,000
Cities Service Company	Copperhill, TN	Smelter	20,000
Copper Range Company	White Pine, MI	Smelter/refinery	82,000/82,000
Inspiration Consolidated Copper Company	Miami, AZ	Smelter/refinery	64,000/136,000
Kennecott Copper Corporation	Garfield, UT	Smelter	254,000
	Hurley, NM	Smelter/refinery	73,000/93,000
	Hayden, AZ	Smelter	73,000
	McGill, NV	Smelter	45,000
	Baltimore, MD	Refinery	250,000
	Magna, UT	Refinery	169,000
Magma Copper Company	San Manuel, AZ	Smelter/refinery	181,000/181,000
Phelps Dodge Corporation	Morenci, AZ	Smelter	161,000
	Douglas, AZ	Smelter	115,000
	Hidalgo, NM	Smelter	91,000
	Ajo, AZ	Smelter	64,000
	El Paso, TX	Refinery	404,000
	Laurel Hill, NY	Refinery	83,000
Southwire Company	Carrollton, GA	Refinery	65,000

of the total copper production. These newer production methods include continuous flash smelting, roast-leach-electrowinning, and hydro-metallurgical processes (U.S. EPA, 1978).

Most of the producers listed in Table 5 own or control domestic mines that supply at least part of their own needs. The three largest domestic producers are Kennecott Copper Corp., Phelps-Dodge Corp., and ASARCO, Inc. (U.S. EPA, 1978).

10. Manufacturing Processes

A flow sheet for the copper industry is given in Figure 5 which includes the various manufacturing operations.

Most copper today is processed by mining, waste leaching and cementation, concentrating, smelting, and refining. Figure 6 illustrates the major steps involved in the conventional approach to recovery and processing of copper. The copper ore from the mine, often containing less than 1% copper, is transported to the concentrator where it is first crushed and then ground with water. The ground ore slurry enters flotation cells, where copper concentrates are collected as a froth. Following dewatering, they enter the smelter. In the smelter the sulfide minerals react with oxygen and fluxes to produce impure copper metal, SO_2, and slag. Smelting occurs in two steps. In the reverberatory furnace, the copper concentrate is melted to produce matte, the mixed sulfides of copper and iron. Next, air is blown through the matte in the converters, producing impure copper plus a slag containing the iron. The impure copper is then cast into anodes and purified by plating onto pure copper in an electrolytic tankhouse (Tuddenham and Dougall, 1979).

11. Impurities or Additives

The purity of finished copper can vary among the manufacturers; however the average impurity levels of wirebar copper are the following (Tuddenham and Dougall, 1979):

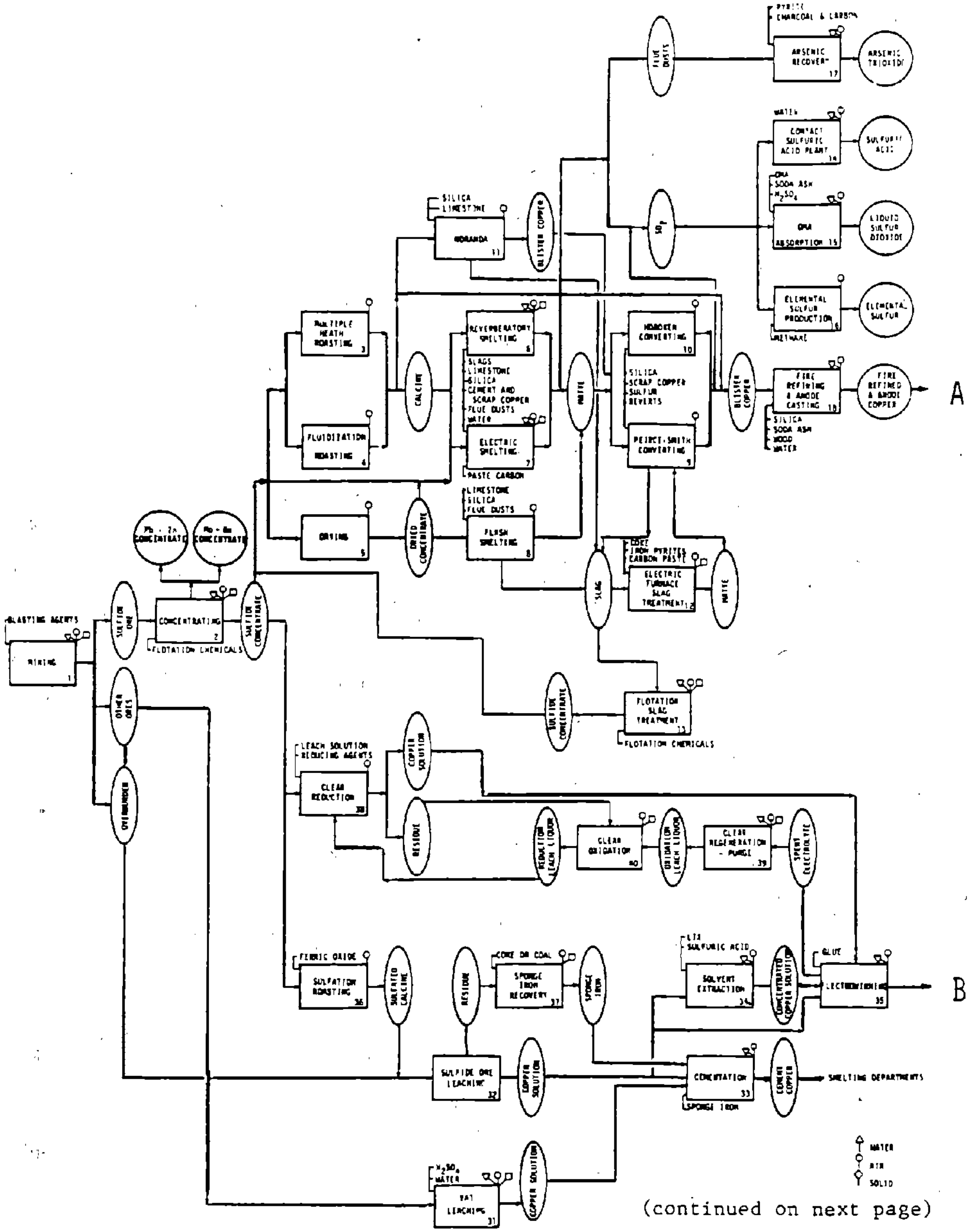


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Figure 5. Copper Industry Flow Sheet (U.S. EPA, 1978)

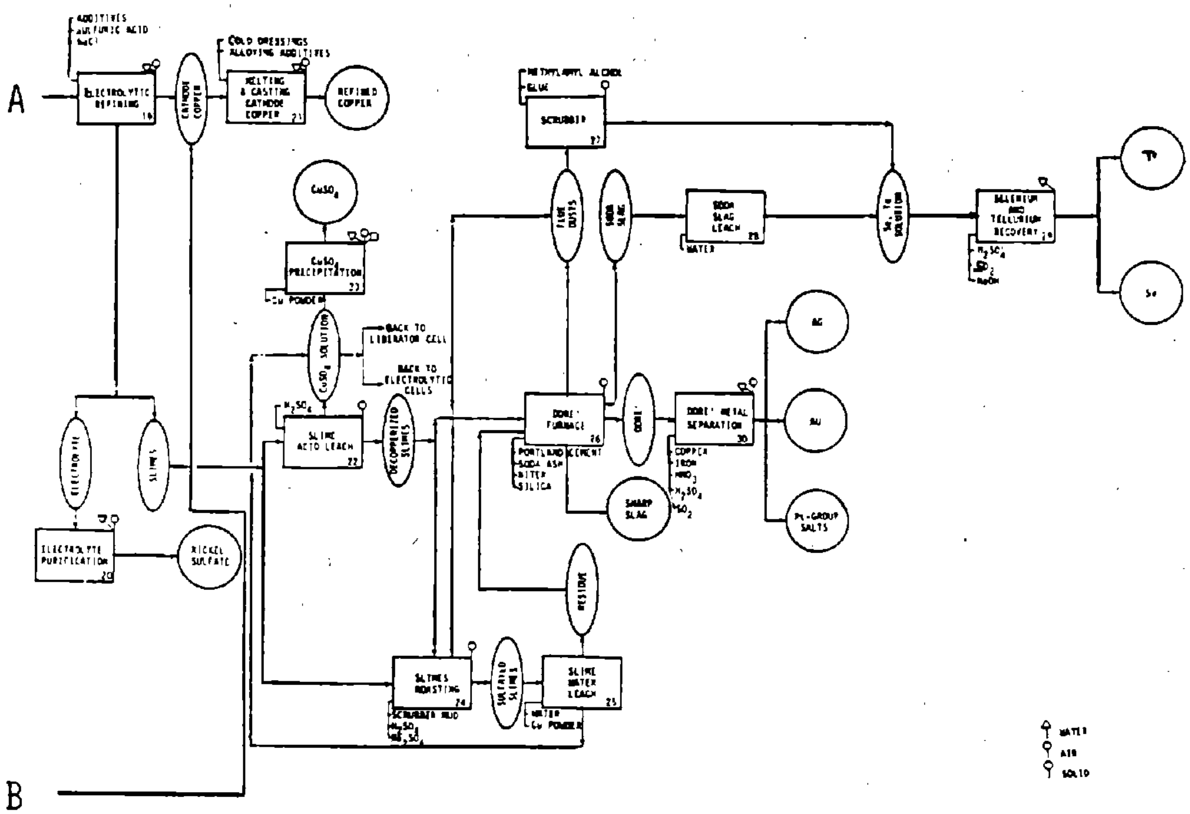


Figure 5. Copper Industry Flow Sheet (U.S. EPA, 1978) (Cont'd)

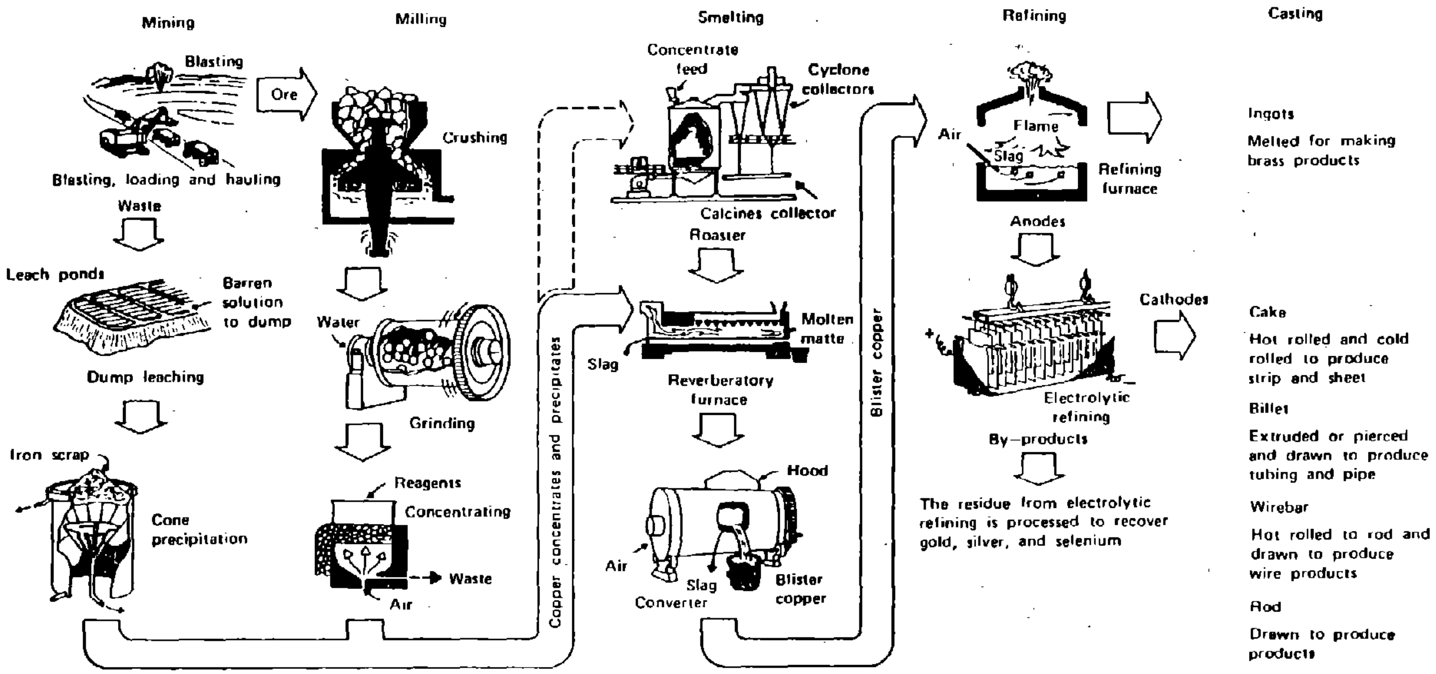


Figure 6. Recovery of Copper from Sulfide Ore (Taken from: Tuddenham and Dougall (1979). In: Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. 6.)

Impurity	Concentration, ppm
antimony	3.41
arsenic	1.39
bismuth	0.36
iron	6.07
lead	4.08
nickel	3.41
oxide	327.25
selenium	1.10
silver	11.19
sulfur	10.00
tellurium	1.16
tin	1.63

Electrolytic copper is one of the purest commercial materials; the average copper content is over 99.95% (Tuddenham and Dougall, 1979). Up to 0.05% oxygen is present in the form of copper(I) oxide.

Copper is alloyed with a variety of metal such as tin, lead, aluminum, etc.

12. Occupational Exposure

The National Occupational Hazard Survey does not provide an estimate of the number of workers who are potentially exposed to copper metal.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper were not found in the literature searched.

14. Biological Effects

A. Animal Studies

1. Acute Exposures

The acute toxicity of copper is summarized in Table 6.

Information on the general toxicologic effects resulting from acute exposure is scarce, particularly for non-ruminant mammals. In sheep, the signs of acute copper toxicity are abdominal pain, excessive salivation, vomiting, and greenish fluid diarrhea. Collapse and death occur within 24-48 hours of administration of a fatal dose (NRC, 1977).

Table 6. Acute Effects of Copper

Compound	Route	Species	Dose	Response	Reference
Copper(II) ion	i.p.	mice	2.86[a]	LD50	Bienvenu _et_ _al_., 1963
Copper(II) ion	i.p.	mice	1.4[b]	LD01	Franz, 1962
Copper(II) ion	i.p.	mice	3.5[b]	LD50	Franz, 1962
Copper(II) ion	i.p.	mice	9.1[b]	LD99	Franz, 1962

[a] The dose for Cu^{2+} was calculated on the basis of the value for copper sulfate.

[b] The dose for Cu^{2+} was calculated on the basis of the value for copper chloride.

2. Subchronic Exposures

Sheep suffering from copper poisoning usually develop hemoglobinemia, hemoglobinuria, and icterus. The hepatocytes may exhibit cytoplasmic vacuolation and necrosis; fibrosis occurs, and kidney tubules become clogged with hemoglobin (NRC, 1977).

Greenberg (1979) implanted a pure copper wire (about 3 mg) into the right renal cortex of 30 Sprague-Dawley rats. After 6 months, examination of the rat kidney revealed only mild renal destruction and fibrosis.

3. Chronic Exposures

No information was found in the literature searched.

4. Carcinogenicity

No information was found in the literature searched.

5. Mutagenicity

Loeb _et al_. (1978) recently found that Cu^{2+} increased the misincorporation of bases into synthetic polynucleotides, which indicates that copper may increase errors in the _in vivo_ replication of DNA.

6. Teratogenicity

No teratologic effects were noted in the fetuses of rats or hamsters in which a copper loop intrauterine device had been inserted on Day 6 of pregnancy (Chang _et al_., 1970).

7. Reproductive Effects

Studies in rodents have demonstrated that intrauterine loops and wires of metallic copper prevent implantation and blastocyst development (Chang _et al_., 1970; Brinster and Cross, 1972; Naeslund, 1972; Whittingham, 1972). Ovarian function, as evidenced by the average number of corpora lutea present, was not inhibited by the presence of copper in the rat uterus (Chang _et al_., 1970). In _in vitro_ tests, cupric ions, cuprous ions, and copper metal have been shown to be embryotoxic to developing mouse blastocysts (Brinster and Cross, 1972; Naeslund, 1972; Whittingham, 1972; Holland and Pike, 1978).

8. Other Relevant Information

No information was found in the literature searched.

b. Human Studies

(1) Pharmacokinetics

Copper is an essential trace element required for human metabolism and is acquired in adequate amounts through most diets (NRC, 1977). Daily intake of dietary copper varies from approximately 15 to 45 μg Cu/kg body weight in adults. Drinking water may supply additional copper in concentrations ranging from a few micrograms to 1 mg/l or more (Schroeder et al., 1966). Copper is absorbed from the gastrointestinal tract in an unknown form and by an unknown mechanism, but absorption appears to be governed by the amount of copper in the body (NRC, 1977). Tests using ^{64}Cu and ^{67}Cu in 7 human volunteers indicated that, on the average, 57% of ingested copper was absorbed (Strickland et al., 1972b), while a balance study on 4 women showed absorption from 49 to 65% (Robinson et al., 1973).

When first absorbed, copper is bound to proteins in the body. Copper is transported to the liver while bound to albumin (Bearn and Kunkel, 1955) and perhaps to amino acids (Neumann and Sass-Kortsak, 1967), and it is stored in the liver in association with a number of proteins (mainly hepatocuprein, copper-chelatin, and metallothionein). From the liver, copper is carried in the blood by ceruloplasmin, a high molecular weight protein, to protein-binding sites in other tissues (Sternlieb et al., 1962; Piscator, 1977).

Fecal excretion is the major route for elimination of copper from the body; the excreted copper represents not only unabsorbed dietary copper, but also copper excreted via the biliary tract (0.5-1.2 mg/day;

Cartwright and Wintrobe, 1964; Frommer, 1974), the gastric and intestinal mucosa (possibly 1 mg/day; Gollan, 1975), and the salivary glands (0.38 to 0.47 mg/day; DeJorge et al., 1964). Small amounts of copper (10 to 60 μg/day) are excreted in the urine (Cartwright and Wintrobe, 1964; Zak, 1958).

Homeostatic mechanisms regulate the retention of ingested copper in the body; however, it is not known whether copper absorbed through the skin, lungs, or uterine mucosa (from intra-uterine devices) is accumulated or excreted (NRC, 1977). The biological half-life of injected copper in normal human beings is about 4 weeks (Strickland, 1972a, 1972b; Dekaban et al., 1975; Tauxe et al., 1966).

(2) Health Effects

Surveys of workers who may be exposed to copper dust or fumes have not revealed any signs of chronic disease (Hamilton and Hardy, 1974).

Health problems associated with copper fume exposure include upper respiratory irritation, nausea, altered taste (metallic or sweet), "metal fume fever," and sometimes skin and hair discolorations. Altered taste was noted on short exposures to copper fumes in concentrations of 1 to 3 mg/m^3 (ACGIH, 1977).

Congestion of nasal mucous membranes and the pharynx, with occasional ulcers and perforation occurring on the nasal septum, have been observed as a consequence of inhaling copper salt dusts or mists. Ingested in large amounts, copper salts may irritate the gastrointestinal tract and induce gastric pain, nausea, vomiting, diarrhea, bleeding gastritis, and salivation. Hopper and Adams (1958) described five different incidences of copper poisoning which occurred from a carbonated beverage dispensed from a post-type vending machine. By simulating the field conditions in a controlled experiment, it was demonstrated that the carbon dioxide or carbonated water could react with the copper in the connective tubing and/or the water filter. Generally, acute gastric upset ensued within 15 minutes after ingestion of the beverage. Analysis of the beverage in question revealed levels of copper as low as 35 ppm. Eczema results from skin contact with copper salts, while conjunctivitis and occasional ulceration and corneal opacity may occur when copper salts are applied to the eye (ACGIH, 1979).

Metal fume fever is most likely caused by exposure to freshly produced copper oxide from fine copper dusts or fumes (McCord, 1960). The illness lasts 24 to 48 hours and is characterized by fever, chills, aching muscles, headache, and a dry mouth and throat. Gleason (1968) described one case that resulted from exposure to fine copper dust at concentrations of approximately 0.1 mg/m^3.

Fragments of metallic copper in the eye (chalcosis bulbi) can cause sunflower cataracts, noticeable deposits of copper in the cornea known as Kayser-Fleishcher rings (Hanna and Fraunfelder, 1973; Rosen, 1949), or loss of the eye.

(3) Target Organ Toxicity

Human (and animal) studies have shown that, following oral administration, copper concentrates in the liver and brain, with lesser amounts in the heart, kidney, spleen, blood, and muscles (Adelstein and Vallee, 1961; Cartwright and Wintrobe, 1964; Owen, 1965; Schroeder *et al*., 1966; Sandstead *et al*., 1970; Sumino *et al*., 1975).

In humans, ingestion of excessive amounts of copper has resulted in gastrointestinal disturbances, renal and hepatic injury, and blood changes. Inhalation of mists and dusts causes irritation to the upper respiratory tract and nasal mucosa (Piscator, 1977; NRC, 1977).

Excessive deposits of copper in the liver, and later in the brain and kidneys as well, occur with Wilson's disease, a genetic defect in copper metabolism. If left untreated, this syndrome results in fatal injury to the brain, central nervous system, or kidneys (NRC, 1977).

(4) Epidemiology

Several studies have found increased incidences of lung cancer (Pinto and Bennet, 1963; Pinto et al., 1977; Kuratsune et al., 1974; Lee and Fraumeni, 1969; Milham and Strong, 1974; Tokudome and Kuratsune, 1976) and mortality from cardiovascular disease (Lee and Fraumeni, 1969; Axelson et al., 1978) among workers in copper smelters, but it appears that the cancer is caused by exposure to arsenic trioxide in the dust and fumes produced by the various pyrometallurgic processes, and not to copper.

15. Ongoing Studies

Several studies on copper and copper compounds are currently being conducted. See Appendix B for details.

16. Exposure Standards

ACGIH (1981) has recommended a Threshold Limit Value-Time Weighted Average (TLV-TWA) of 0.2 mg/m^3 for copper fumes and 1 mg/m^3 for copper dusts and mists. The recommended Threshold Limit Value-Short Term Exposure Limit (TLV-STEL) for copper dusts and mists is 2 mg/m^3 (ACGIH, 1981). The Occupational Safety and Health Administration (OSHA, 1978) has adopted exposure limits (8-hour Time Weighted Average) of 0.1 mg/m^3 for copper fume and 1 mg/m^3 for copper dusts and mists.

17. Sources of Additional Relevant Information

"Environmental Conditions in U.S. Copper Smelters" (NIOSH 75-158) has been published by NIOSH.

NIOSH Health Hazard Evaluations (HHE's) relating to copper have been conducted at the following sites:

Location	HHE No.
1. American Concrete Division, Union Metal Co., Waukegan, IL	HHE 78-47-570
2. Anaconda Company, Anaconda, MT	HHE 73-164-169
3. Bohn Aluminum and Brass Corp., Danville, IL	HHE 76-1-388
4. Cities Service Co., Miami, AZ	HHE 79-10-576
5. Dunlop Tire and Rubber Co., Huntsville, Al	HHE 73-93-199
6. EPC of Arkansas, Fayetteville, AR	HHE 73-177-147
7. Federal-Mogul Corp., Oallipolils, OH	HHE 73-149-140
8. General American Transportation Corp., Masury, OH	HHE 77-41-505
9. Inland Steel Corp., East Chicago, IN	HHE 77-31-432
10. International Harvester, Springfield, OH	HHE 78-63-574
11. Kennecott Smelter, Garfield, UT	HHE 78-136-643
12. Melroe Division of Clark Equipment Co., Gwinner, ND	HHE 78-87-573
13. Rheem Manufacturing Co., Fort Smith, AR	HHE 73-138-156
14. Schulmerich Carillons, Inc., Sellersville, PA	HHE 73-161-201
15. Sterns-Roger Fabrications, Inc., Denver, CO	HHE 79-112-636
16. Strum Machine Co., Inc., Barboursville, WV	HHE 72-92-93

In addition to the HHE's, two Walk-Through Surveys of copper facilities were also conducted by NIOSH:

1. Reading Brake and Alignment Service, Cincinnati, OH. (unnumbered)
2. Wood Preservative Production Facility at Koppers Co., Inc., Forest Products Group Speciality Wood Chemical Division, Valparaiso, IN. (unnumbered)

18. Other Pertinent Data

No other information that would aid in the assessment of copper as an occupational hazard was found in the literature searched.

B. COPPER(II) ACETATE

1. Chemical Name: Copper(II) Acetate

2. Chemical Structure: $Cu(C_2H_3O_2)_2 \cdot H_2O$

3. Synonyms: Acetic acid, copper (2+) salt, monohydrate
Copper(II) acetate, monohydrate
Crystallized verdigris
Crystals of Venus
Cupric acetate
Neutrallized verdigris

4. Chemical Abstract Service (CAS) Number: 142-71-2

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:
AG3500000

6. Chemical and Physical Properties:

Description:	greenish-blue to dark green solid
Molecular Weight:	199.65
Boiling Point:	decomposes at 240°C
Melting Point:	115°C
Vapor Pressure:	---
Solubility:	7.2 g/100 cc cold water; 20 g/100 cc hot water; soluble in alcohol; slightly soluble in glycerol and ether
Specific Gravity:	1.93
Stability:	tends to effloresce in dry air

7. Production

The most recent production volume available from the Trade Commission is 291 thousand pounds in 1973 (USITC, 1975).

Data available from the U.S. EPA (1980) regarding producers of copper(II) acetate and production volumes are presented in Table 7.

8. Use

Copper(II) acetate is an effective catalyst in many polymerization processes involving styrene, acrylonitrile, vinyl pyridine, and others. It

Table 7. Producers of Copper(II) Acetate and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
Haven Chemical Philadelphia, PA	Manufacturer	under 1000 lb
U.C.C. Site No. 02-305 Ambler, PA	Manufacturer	under 1000 lb
Kocide Chemical Corp. Houston, TX	Manufacturer	confidential
St. Louis Plant St. Louis, MO	Manufacturer	confidential
CP Chemicals, Inc. Sewaren, NJ	Manufacturer	confidential
J.T. Baker Chem. Phillipsburg, NJ	Manufacturer	10-100 thousand lb
George Uhe Co. New York City, NY	Importer	10-100 thousand lb
American Int'l Chem. Natick, MA	Importer	confidential
Plant Site Not on File	---	10-100 thousand lb

is also used as a preservative for cellulosic materials, a stabilizer for polyurethanes and nylon, and as a pigment and pigment intermediate (Kust, 1979). Other uses include fungicide applications, textile dyeing, and production of the basic acetate (Winter *et al*., 1965; Lawler, 1977).

A breakdown of the percentages of the total amount of copper acetate produced that are used in various applications is not available.

9. Manufacturers and Distributors

SRI International (1980) lists the following manufactuers:

Allied Chem.	Marcus Hook, PA
J.T. Baker Chem.	Phillipsburg, NJ
C.P. Chem.	Sewaren, NJ
Kocide Chem.	Houston, TX
Mallinckrodt	St. Louis, MO

In addition to the manufactuers, the distributors include (*1980-81 OPD Chemical Buyers Directory*, 1980; *Chemical Week: 1981 Buyers' Guide Issue*, 1980; *Chem Sources--USA*, 1980):

Alfa Prod.
Amer. Int'l. Chem.
Anachemia Chem.
ARS Chem.
Atomergic Chemetals
Chem Services
Chempar Chem.
Covinter Inc.
Delamar Inc.
EM Lab
Filo Chem.
Fisher Sci.
Gallard-Schelsinger
Hetako Chem.
LaPine Chem.
MCB Reagents
Mechema, Ltd.
Metron, Inc.
Mineral Res. and Devel.
Orion Chem.
Pacific Gateway
Pfaltz and Bauer
Phillip Bros. Chem.
Reliable Chem.
Sigma Chem.
Signo Trading
Spex Indus.
Tridom Chem.
George Uhe Co.
United Mineral and Chem.

10. Manufacturing Processes

Copper(II) acetate is usually manufactured by the action of hot acetic acid on cupric oxide, carbonate, or metal (Kust, 1979; Winter *et al*., 1965). The acetic acid solution is boiled and the acetic acid-water vapors are passed, along with air, through a column of copper shot located above the boiler. The vapors condense above the shot and are refluxed back through the shot and returned to the boiler. The solution builds up in cupric acetate and can be withdrawn continuously or batchwise. Crystallization yields the acetate and the mother liquor is returned to the still. The crystals are centrifuged, washed, and dried. Figure 1 in Section II of this report depicts the general process scheme.

11. Impurities or Additives

No information was found in the literature searched.

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 596 workers are potentially exposed to copper acetate.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) acetate were not found in the literature searched.

14. Biological Effects

a. Animal Studies

(1) Acute Exposures

Information on the acute toxic effects of copper acetate is scarce. An oral LD_{50} of 710 mg/kg has been reported, however, in male Wistar rats (Smyth et al., 1969).

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

(4) Carcinogenicity

No information was found in the literature searched.

(5) Mutagenicity

Copper acetate was tested for its ability to affect the accurcy of DNA synthesis *in vitro* (Sirover and Loeb, 1976). A copper concentration of 0.12 mM increased the error frequency by more than 30 percent.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

The metabolism of copper in the adult male rat was investigated by Owen (1965) using 100 μg of copper as copper acetate-Cu^{64}. The liver, kidney, and gastrointestinal tract concentrated the Cu^{64} rapidly following intravenous administration. Thereafter, the level of Cu^{64} in these tissues steadily decreased due to excretion into the bile, urine, and feces, respectively. These authors suggested the ceruloplasmin may be the copper donor for the tissues.

b. Human Studies

(1) Pharmacokinetics

In an attempt to clarify certain aspects of Wilson's disease, Bearn and Kunkel (1955) examined the distribution and excretion of intravenously injected radioactive Cu^{64} (in the form of copper acetate or copper nitrate) in normal subjects and patients with Wilson's disease. An extremely rapid decrease, followed by a larger increase, in serum radioactively was observed in normal subjects. In patients with Wilson's disease, the decrease in serum radioactivity was slower and was not followed by a subsequent increase. It was demonstrated in normal subjects that the rise in serum radioactivity was due to its incorporation into ceruloplasmin and, since this protein is deficient in

Wilson's diesease, no increase in serum radioactivity was noted in these patients. Excess administered copper associated with serum albumin persisted much longer in patients with Wilson's disease than in control subjects. In Wilson's disease subjects, total radioactivity excretion in the urine was grater than, and fecal excretion was less than, that found in normal subjects.

(2) Health Effects

No information was found in the literature searched.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) acetate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) acetate as an occupational hazard was found in the literature searched.

C. COPPER(II) ARSENATE

1. Chemical Name: Copper(II) Arsenate

2. Chemical Structure: $Cu_3(AsO_4)_2$

3. Synonyms: Arsenic acid, copper salt
   Arsenic acid, copper (2+) salt (2:3)
   Copper(II) orthoarsenate
   Cupric arsenate

4. Chemical Abstract Service (CAS) Number: 7778-41-8
   10103-61-4

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   Not listed

6. Chemical and Physical Properties:

Description:	light blue to blue-green powder
Molecular Weight:	540.52 (tetrahydrate)
Boiling Point:	---
Melting Point:	---
Vapor Pressure:	---
Solubility:	Insoluble in water and alcohol; soluble in dilute acids, ammonium hydroxide
Specific Gravity:	---
Stability:	---

7. Production

Production figures are not available from the U.S. EPA (1980); however, based on consumption figures below, annual production of copper(II) arsenate is in excess of one million pounds.

8. Use

Copper arsenate is primarily used in wood preservation in a form commercially known as chromated copper arsenate (Trotz and Pitts, 1981; Hartford, 1979). Chromated copper arsenate (CCA), $Cu_3(AsO_4) \cdot NaCr_2O_7$ (Chemical Abstract Service No. 37337-13-6), is a product containing varying percentages of copper arsenate and sodium dichromate. It is applied as a water-borne salt that is injected into wood where it reacts with cellulose and establishes long-term protection against fungi, marine organisms, termites, and other insects. The treated wood is free from bleeding, is paintable, and has an olive-green color. It is widely used in treating utility poles, building lumber, and wood foundations. Consumption figures for CCA in 1976 are listed below (Hartford, 1979):

	Consumption (millions of pounds)	Sodium Dichromate equivalent (millions of pounds)
Type A CCA	2.46	2.39
Type B CCA	4.59	2.41
Type C CCA	10.04	7.11
	17.09 Total	

In 1978, a total of 18.2 million pounds of CCA were consumed (Trotz and Pitts, 1981).

Copper arsenate is also used as an insecticide and as an emulsifying agent (Kust, 1979).

9. Manufacturers and Distributors

The U.S. EPA (1980) lists CP Chemicals (Sumter, SC and Sewaren, NJ) as a manufacturer (no production ranges available) and Cominco Amer. Inc. (Spokane, WA) as an importer of under 1000 pounds in 1977. Trotz and Pitts (1981) list Koppers Co. as a producer of chromated copper arsenate.

Distributors include (Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Atomergic Chemetals
City Chem.
Corac Inc.
Orion Chem.
Pfaltz and Bauer
Reliable Chem.

10. Manufacturing Processes

Copper(II) arsenate is prepared by the reaction of copper sulfate with sodium arsenate or arsenic acid followed by neutralization with sodium carbonate or hydroxide (Kust, 1979). Figure 2 in Section II outlines a general manufacturing scheme.

11. Impurities or Additives

As described in Section 8, copper(II) arsenate is normally industrially in solution containing sodium dichromate.

12. Occupational Exposure

The National Occupational Hazard Survey does not provide an estimate of the number of workers who are potentially exposed to copper(II) arsenate.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) arsenate were not found in the literature searched.

14. Biological Effects

No information on the biological effects of copper(II) arsenate was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) arsenate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) arsenate as an occupational hazard was found in the literature searched.

D. COPPER(II) CARBONATE, BASIC

1. **Chemical Name**: Copper (II) Carbonate, basic

2. **Chemical Structure**: $CuCO_3Cu(OH)_2$ (variable)

3. **Synonyms**: Bremen blue
Bremen green
Copper carbonate hydroxide
Copper, carbonato(2-) dihydroxydi-
Cupric carbonate, basic
Cupric subcarbonate
KOP Karb
Malachite

4. **Chemical Abstracts Service (CAS) Number**: 12069-69-1
1184-64-1

5. **Registry of Toxic Effects of Chemical Substances (RTECS) Number**:

GL6910000

6. **Chemical and Physical Properties**:

Description:	green to blue powder
Molecular Weight:	221.11
Boiling Point:	---
Melting Point:	decomposes at 200°C
Vapor Pressure:	---
Solubility:	insoluble in water; soluble in acids
Specific Gravity:	$\approx$4.0
Stability:	non-flammable

7. **Production**

Data available from the U.S. EPA (1980) regarding producers of copper (II) carbonate and production volumes are presented in Table 8.

Annual production is likely in excess of one million pounds (SRC estimate).

8. **Use**

Copper carbonate is produced commercially in two grades--light and dense. It is used in pyrotechnics, in paint and varnish pigments, in ceramic

Table 8. Producers of Copper(II) Carbonate and Production Ranges (U.S. EPA, 1980)

Producer and Location	Type of Producer	1977 Production Range
		CAS No. 12069-69-1
Mineral Research and Development Corp. Concord, NC	Manufacturer Produced Site Limited	confidential
Kocide Chemical Houston, TX	Manufacturer	confidential
Cities Services Co. Copperhill, TN	Manufacturer	confidential
United Catalysts Inc. Louisville, KY	Manufacturer	2-20 thousand lb
The Shepherd Chemical Co. Cincinnati, OH	Manufacturer	confidential
St. Louis Plant St. Louis, MO	Manufacturer	zero
The Harshaw Chemical Co. Cleveland, OH	Manufacturer	zero
Leffingwell Chemical Co. Brea, CA	Manufacturer	10-100 thousand lb
Henkel Inc. Teaneck, NJ	Importer	under 1000 lb
Calabrian International Corp. New York City, NY	Importer	zero
		CAS No. 1184-64-1
Dow Chemical Midland, MI	Manufacturer Manufacturer	10-100 thousand lb 10-100 thousand lb
J.T. Baker Chem. Phillisburg, NJ	Manufacturer	10-100 thousand lb

Table 8. Producers of Copper(II) Carbonate and Production Ranges (U.S. EPA, 1980) (Cont'd)

Producer and Location	Type of Producer	1977 Production Range
Eastman Kodak Rochester, NY	Manufacturer	none
Katalco Corp. Chicago, IL	Manufacturer	confidential
CP Chemical Sewaren, NJ	Manufacturer	confidential
Engelhard Indust Newark, NJ	Manufacturer	under 1000 lb
Calabrian International New York City, NY	Importer	none

frits, in the electroplating industry as a source of copper, in coloring metals, in animal and poultry feeds as a source of copper, and agriculturally as a funcicide for treating seed (Winter et al., 1965).

It is also used as a catalyst in hydrogenations and in the curing of rubber and as a source of copper in the manufacture of other copper salts (Kust, 1979).

A breakdown of the percentages of the total amount of copper (II) carbonate produced that are used in various applications is not available. In 1975, about 0.1 million pounds of copper carbonate were applied as fungicide for citrus and deciduous fruits (Ayers and Johnson, 1976).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers:

Cities Service Co.	
Minerals Group	Copperhill, TN
C.P. Chems., Inc.	Sewaren, NJ
Kocide Chem. Co.	Houston, TX
Mineral Research and Dev. Corp.	Concord, NC
North American Philips Corp.	
Thompson-Hayward Chem. Co., subsid.	
Leffingwell Chem. Co., subsid.	Brea, CA
Philipp Brothers Chems., Inc.	
The Prince Mfg. Co., subsid.	Bowmanstown, PA
	Quincy, IL
Richardson-Merrell, Inc.	
J.T. Baker Chem. Co., subsid.	Phillipsburg, NJ
The Shepherd Chem. Co.	Cincinnati, OH
United Catalysts Inc.	Louisville KY

Data available from the U.S. EPA (1980) regarding producers of copper(II) carbonate and production volumes are presented in Table 8.

In addition to the manufacturers, the distributors include (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Aldrich Chem.
Anachemia Chem.
Apache Chem.
Ashland Chem.
Atomergic Chem.
Barker Indus.
Calabrian International
Canadian Met. Chem.
Chem Services
Chemical Specialities
Chemtech Research
Cities Services
Cometals Inc.
Covinter Inc.
Delamar Inc.
EM Lab.
Faesy and Besthoff Inc.
Filo Chem.
Fisher Sci.
Gallard-Schelsinger
Harshaw Chem.
J.F. Henry Chem.
Kemstar Chem.
LaPine Sci.
MCB Reagents
Mallinckrodt
Mechema Ltd.
Monterey Chem.
Mutchler Chemical
Orion Chem.
Pacific Gateway
Pfaltz and Bauer
Pharmacie Centrale De France
Spex Indus.
Sylvan Chem.
Thomspon-Hayward
Tridom Chem.
Joseph Turner and Co.
Var-Lac-Oid Chem.

10. Manufacturing Processes

Copper carbonate (basic) occurs in nature in monoclinic crystalline form as blue azurite, $2CuCO_3 \cdot Cu(OH)_2$, or as dark-green malachite, $CuCO_3 \cdot Cu(OH)_2$. The basic carbonate is precipitated as a green powder by adding copper sulfate or copper nitrate solution to a solution of soda ash (Winter et al., 1965; Kust, 1979).

The precipitate is allowed to settle, and the mother liquor is separated. The carbonate slurry is then washed (leached) with water to remove the sodium salt formed by the reaction. Filtering and drying completes the process (Winter et al., 1965; Utter and Tuwiner, 1949). Figure 7 outlines the process.

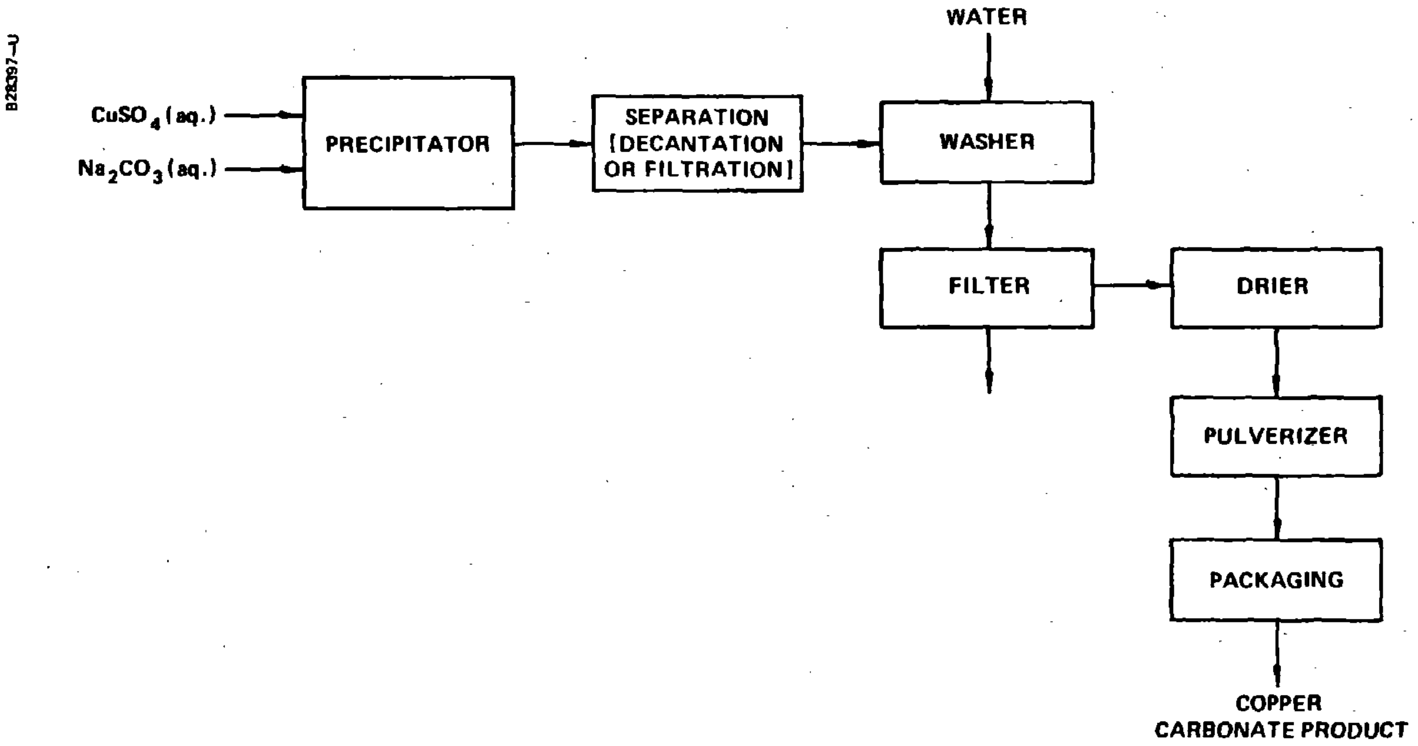


Figure 7. Manufacture of Copper(II) Carbonate, Basic

11. Impurities or Additives

One manufacturer lists the typical analysis as follows (C.P. Chemical, undated):

Copper	55% min
Sulfur	.2%
Iron	.1%
Zinc	.002%
Nickel	.05%
Lead	nil
Manganese	nil
Insoluble in HCl	.05%

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 11,740 workers are potentially exposed to copper(II) carbonate, basic.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) carbonate were not found in the literature searched.

14. Biological Effects

The only information on the biological effects of copper carbonate, basic found in the literature searched is an acute oral LD_{50} dose (rabbits and rodents: 159 mg/kg) reported by the Spector (1956) and a cytological study reported by Kimwa and Makino (1963). In the latter study, intraperitoneal injection of copper carbonate, basic (130mg/kg) induced miotic abnormalities in MTK-sarcoma III rat ascite tumors _in vivo_, as evidenced by chromatic aggregation and stickiness of chromosomes.

15. Ongoing Studies

A number of studies on copper compounds, basic are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) carbonate, basic were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper as an occupational hazard was found in the literature searched.

E. COPPER(I) CHLORIDE

1. Chemical Name: Copper(I) Chloride

2. Chemical Structure: CuCl

3. Synonyms: Cuprous chloride
   Cu-lyt

4. Chemical Abstracts Service (CAS) Number: 7758-89-6

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   GL6990000

6. Chemical and Physical Properties:

Description:	white crystalline powder
Molecular Weight:	98.99
Boiling Point:	1366-1490°C
Melting Point:	422-430°C
Vapor Pressure:	---
Solubility:	0.0062 g/100 g (cold water); practically insoluble in alcohol and acetone; soluble in acids, ammonia, ether
Specific Gravity:	3.53
Stability:	oxidizes and hydrolyzes in moist air to the basic chloride

7. Production

Data available from the U.S. EPA (1980) regarding producers of copper(I) chloride and production volumes are presented in Table 9.

8. Use

Copper(I) chloride has a wide range of uses. It is useful as a catalyst for organic reactions (oxidation of olefins and acrylonitrile from acetylene and hydrogen chloride), as a battery electrolyte, as a textile bleach, as a ceramic decolorizer, in soldering fluxes, as a stabilizer in nylon manufacturing, as an antioxidant in cellulose solutions, as a desulfurizing agent in the petroleum industry, and as a condensing agent for soaps, fats, and oils (Kust, 1979; Winter et al., 1965).

Table 9. Producers of Copper(I) Chloride and Production Ranges (U.S. EPA, 1980)

Producer and Location	Type of Producer	1977 Production Range
McGean Chemical Co. Cleveland OH	Manufacturer	0.1 to 1 million lb
Haven Chemical Co. Philadelphia, PA	Manufacturer	under 1000 lb
E&I& duPont de Nemours Niagara Falls, NY	Manufacturer Produced Site Limited	1 to 10 million lb
CP Chemicals Inc. Powder Springs, GA	Manufacturer	confidential
The Ore and Chemical Corp. New York City, NY	Importer	zero
United Mineral and Chemical Corp. New York City, NY	Importer	under 1000 lb
EM Laboratories Inc. Elmsford, NY	Importer	1 to 10 thousand lb
American Hoescht Corp. Bridgewater, NJ	Importer	confidential
Sumitomo Shoji America New York City, NY	Importer	10 to 100 thousand lb
SCM Corp. Jacksonville, FL	Importer	confidential
Calabrian International Corp. New York City, NY	Importer	under 1000 lb

A breakdown of the percentages of the total amount of copper (I) chloride produced that are used in various applications is not available; however, uses as catalysts probably consume the greatest amounts of cuprous chloride (SRC estimate).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers:

Chemetals Corp.	Curtis Bay, MD
C.P. Chems., Inc.	Powder Springs, GA
McGean Chem. Co., Inc.	Cleveland, OH
Southern California Chem. Co., Inc.	Garland, TX Santa Fe Springs, CA

Data available from the U.S. EPA (1980) regarding producers of copper(I) chloride and production volumes are presented in Table 9.

The many distributors of copper(I) chloride include 1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Aldrich Chem.
Alfa Prod.
Anachemia Chem.
Apache Chem.
Atomergic Chemetals
Badman Chem.
J.T. Baker, Chem.
Calabrian International
Campbell Chem.
Cerac Inc.
Chem Services
Delamar
Diamond Shamrock
Filo Chem.
Fisher Scientific
Gallard-Schelsinger
D. F. Goldsmith,
Great Western Inorganics
J.F. Henry, Chem.
Hetako Chem.
ICD Group Inc.
ICN/K and K
LaPine Sci.
MCB Reagents
Mallinckrodt
Mechema Ltd.
Millmaster Chem.
Monomer-Polymer and Dajac
Pacific Gateway
Pfaltz and Bauer
Philipp Bros. Chem.
Reliable Chem.
Robeco Chem.
Samincorp
Spex Indust.
Tridom Chem.
George Uhe Co.
United Mineral and Chem.

10. Manufacturing Processes

Cuprous chloride can be made by two different commercial processes (Winter et al., 1965). The solid salt is best prepared by passing chlorine into molten cuprous chloride containing an excess of copper metal. The molten cuprous chloride is cast, cooled, and, if desired, ground to a powder. The second manufacturing method is satisfactory for some purposes, such as the preparation of other cuprous salts. Here, a solution of cupric chloride, hydrochloric acid, and sodium chloride is heated with copper metal until the reduction to cuprous chloride is completed. The cuprous chloride solution is then used as the product of commerce.

11. Impurities or Additives

One manufacturer gives the following typical analysis (C.P. Chemicals, undated):

Assay as CuCl	99.5%
Cupric copper as Cu	0.5%
Total copper as Cu	64.0%
Iron as Fe	0.015%
Acid insoluble	0.05%

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 5,071 workers are potentially exposed to copper(I) chloride.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(I) chloride were not found in the literature searched.

14. Biological Effects

a. Animal Studies

(1) Acute Exposures

No information was found in the literature searched.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Effects

No information was found in the literature searched.

(4) Carcinogenicity

No information was found in the literature searched.

(5) Mutagenicity

Copper(I) chloride was inactive in the rec-assay with Bacillus subtilis (Nishioka, 1975; Kanematsu et al., 1980). In a study of the cytological effect of copper(I) chloride (120 mg/kg body weight administered intraperitoneally) on the MTK-sarcoma III rat ascite tumor in vivo, Kimura and Makino (1963) reported the development of mitotic abnormalities, as evidenced by contraction or stickiness of metaphase chromosomes.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

b. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

No information was found in the literature searched.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(I) chloride were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(I) chloride as an occupational hazard was found in the literature searched.

F. COPPER(II) CHLORIDE

1. Chemical Name: Copper (II) Chloride

2. Chemical Structure: $CuCl_2$ (anhydrous) $CuCl_2 \cdot 2H_2O$ (dihydrate)
3. Synonyms: Copper bichloride
   Copper dichloride
   Cupric chloride
4. Chemical Abstracts Service (CAS) Number: 7447-39-4 (anhydrous)
   10125-13-0 (dihydrate)

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:
   GL7000000 (anhydrous)
   GL7040000 (dihydrate)

6. Chemical and Physical Properties:

Description:	green to blue powder or crystals (dihydrate) yellow to brown deliquescent powder (anhydrous)
Molecular Weight:	134.45 (anhydrous) 170.47 (dihydrate)
Boiling Point:	decomposes at 993°C (anhydrous)
Melting Point:	620°C (anhydrous)
Vapor Pressure:	---
Solubility:	70.6 g/100 g water (0°C) (anhydrous); soluble in alcohol and acetone 110.4 g/100 g water (0°C) (dihydrate); soluble in alcohol, acetone, ethyl acetate; slightly soluble in ether
Specific Gravity:	3.386 (anhydrous) 2.54 (dihydrate)
Stability:	---

7. Production

Data available from the U.S. EPA (1980) regarding producers of copper(II) chloride and production volumes are presented in Table 10.

8. Use

Copper(II) chloride is widely used as a catalyst in many applications (e.g., halogenation of hydrocarbons, in organic oxidation reactions, and in sweetening petroleum oil), particularly in chlorination reactions (Kust,

Table 10. Producers of Copper(II) Chloride and Production Ranges (U.S. EPA, 1980)

Producer and Location	Type of Production	1977 Production Range
McGean Chemical Co. Cleveland, OH	Manufacturer	1 to 10 thousand lb
Fidelity Chemical Prod. Corp. Newark, NJ	Manufacturer	1 to 10 thousand lb
Valumet Processing Corp. Sayreville, NY	Manufacturer	10 to 100 thousand lb
E.I. duPont de Nemours Niagara Falls, NY	Manufacturer Produced Site Limited	1 to 10 million lb
J.T. Baker Chemical Co. Phillipsburg, NJ	Manufacturer	1 to 10 thousand lb
G. Fredrick Smith Chemical Co. Columbus, OH	Manufacturer	under 1000 lb
Macdermid Inc. Waterbury, CT	Manufacturer	confidential
Harstan Chemical Corp. Brooklyn, NY	Manufacturer	confidential
CP Chemicals Inc. Sewaren, NJ	Manufacturer	confidential
The Ore and Chemical Co. New York City, NY	Importer	zero
United Mineral and Chemical Corp. New York City, NY	Importer	1 to 10 thousand lb
Filo Chemical Corp. New York City, NY	Importer Small Manufacturer	confidential
EM Laboratories, Inc. Elmsford, NY	Importer	zero

Table 10. Producers of Copper(II) Chloride and Production Ranges (U.S. EPA, 1980) (Cont'd)

Producer and Location	Type of Production	1977 Production Range
American Hoescht Corp. Bridgewater, NJ	Importer	zero
Ciba-Geigg Corp. Ardsley, NY	Importer	confidential
Calabrian International New York, NY	Importer	zero
Unnamed	---	0.1 to 1 million lb

1979; Winter et al., 1965). It is employed as a wood preservative, as a disinfectant, as a fuel additive, as a glass and ceramic pigment, as a mordant in textile dyeing, as a pyrotechnic ingredient, and as an absorber of NO gas (Kust, 1979; Winter et al., 1965). Other uses include intermediate use to make other copper compounds, photographic compositions, and water purification (Lawler, 1977).

A breakdown of the percentages of the total amount of copper(II) chloride produced that are used in various applications is not available; however, it is judged that catalyst applications consume the greatest amounts of copper(II) chloride (SRC estimate).

9. Manufacturers and Distributors

The following are listed as manufacturers by SRI International (1980):

Gulf Oil Corp.	
Harshaw Chem. Co., subsid.	
Catalyst Dept.	Elyria, OH
Indust. Chems. Dept.	Elyria, OH
McGean Chem. Co., Inc.	Cleveland, OH
Southern California Chem. Co., Inc.	Bayonne, NJ
	Garland, TX
	Santa Fe Springs, CA

Data available from the U.S. EPA (1980) regarding producers of copper(II) chloride and production volumes are presented in Table 10.

The many distributors of copper(II) chloride include 1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980:

ARS Chem.
Aldrich Chem.
Alfa Products
American Hoeschst Corp.
Anachemia Chem.
Apache Chem.
Atomergic Chemetals
Auric Corp.
Badman Chem.
Barker Ind.
Calabrian Int.
Great Western Inorganics
Harstan Chemical Corp.
J.F. Henry, Chemical Co., Inc.
Hetaka Chem.
Hudson Lab.
ICD Group Inc.
ICN/K and K
LaPine Sci.
MCB Reagents
Madison Industries, Inc.
Mallinckrodt

Campbell Chem.
Captree Chemical Corp.
Cerac Inc.
Chem Services
Delamar
Diamond Shamrock
EM Laboratories, Inc.
Faesy and Besthoff, Inc.
Fehr Bros. Chem.
Fidelity Chem.
Filo Chemical Corp.
Fisher Scientific Co.
Gallard-Schelsinger
Mechema Ltd.
Mineral Research and Devel.
Noah Chem.
Orion Chem.
Pacific Gateway
Pfaltz and Bauer
Phillip Bros. Chem., Inc.
Reliable Chem.
Sigma Chem.
Spex Ind.
Tridom Chem.
Joseph Turner and Co.
George Uhe Co., Inc.
United Mineral and Chemical Corp.

10. Manufacturing Processes

Cupric chloride solution can be prepared by passing chlorine up a tower packed with scrap or shot copper, and simultaneously recycling cupric chloride solution over the tower. Hot cupric chloride solution is with-drawn continuously from the bottom of the tower, and makeup water and copper metal are added to maintain a material balance. $CuCl_2 \cdot 2H_2O$ is crys-tallized by cooling, and the mother liquor is returned to the system (Winter et al., 1965). The crystals can then be washed and dried. Anhydrous cupric chloride can be formed by dehydrating the $CuCl_2 \cdot 2H_2O$. This process is shown in Figure 8.

Copper(II) chloride can also be prepared by direct metathesis using cupric sulfate and barium chloride. The anhydrous chloride can also be made by reacting $FeCl_3$ with CuS (Kust, 1979).

11. Impurities or Additives

One manufacturer lists the following typical analysis (C.P. Chemicals, undated):

$CuCl_2 \cdot 2H_2O$	97.7%
Cu	36.4%
Fe	0.02%
Zn	0.04%
SO_4	<0.10%
Alkalies as SO_4	0.20%
pH (5% solution)	3.0
H_2O insoluble	<0.05%

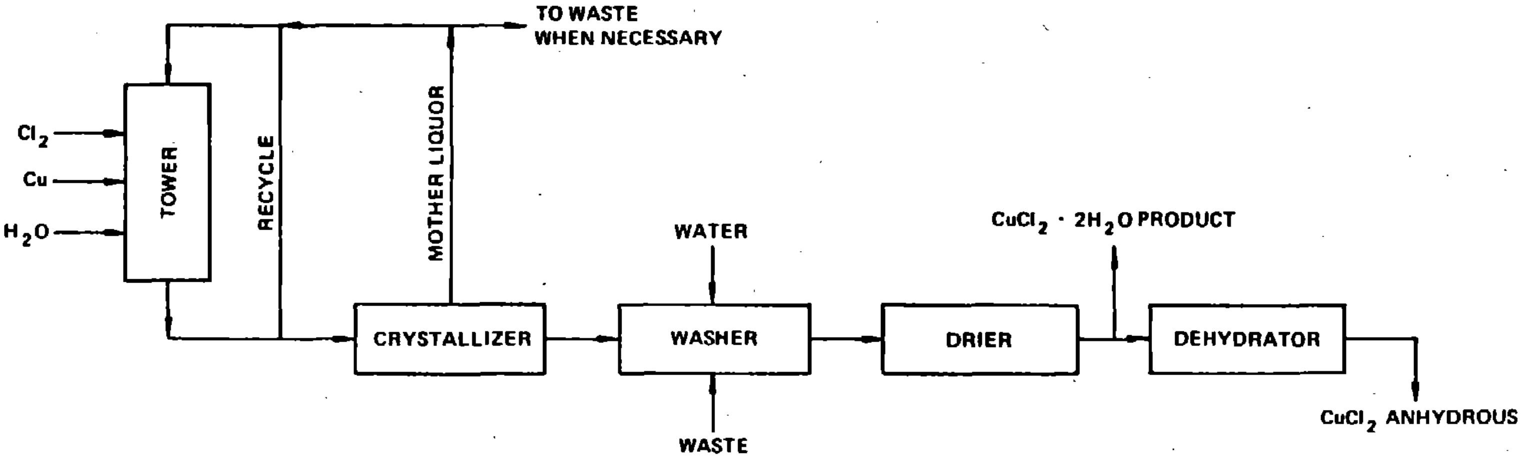


Figure 8. Manufacture of Copper(II) Chloride

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 32,842 workers are potentially exposed to copper(II) chloride.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) chloride were not found in the literature searched.

14. Biological Effects

a. Animal Studies

(1) Acute Exposures

The acute toxicity of copper(II) chloride is summarized in Table 11. The National Research Council (NRC, 1977) reported that, when administered to sheep, copper chloride is 2 to 4 times more toxic than is copper sulfate. A single dose of 20 to 100 mg/kg will lethally poison sheep. Information on the general toxicologic effects resulting from acute exposure is scarce, particularly for non-ruminant mammals. In sheep, the signs of acute copper toxicity are abdominal pain, excessive salivation, vomiting, and greenish fluid diarrhea. Collapse and death occur within 24-48 hours of administration of a fatal dose (NRC, 1977).

It was reported in an abstract of a Russian study that 0.01-0.1 mg/kg copper(II) chloride, administered to rabbits by intravenous injection daily for five to six days, decreased the response of the neuromuscular system to stimuli (Bekh, 1972). The inhibitory effect was greatest on the spinal reflexes as indicated by increased chronaxy and poor ocular accomodation.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

Table 11. Acute Effects of Copper(II) Chloride

Compound	Route	Species	Dose (mg/kg)	Response	Reference
Copper (II) chloride	oral	rats	140	LD50	Calvery, 1942
Copper (II) chloride	oral	guinea pigs	31	LD50	Calvery, 1942
Copper (II) chloride	oral	mice	190	LD50	Calvery, 1942
Copper (II) chloride	i.p.[a]	mice	2.9	LD01	Franz, 1962
Copper (II) chloride	i.p.	mice	7.4	LD50	Franz, 1962
Copper (II) chloride	i.p.	mice	19.3	LD99	Franz, 1962
Copper (II) chloride, dihydrate	i.p.	mice	3.7	LD01	Franz, 1962
Copper (II) chloride, dihydrate	i.p.	mice	9.4	LD50	Franz, 1962
Copper (II) chloride, dihydrate	i.p.	mice	24.5	LD99	Franz, 1962

[a] i.p. = intraperitoneal

(4) Carcinogenicity

No information was found in the literature searched.

(5) Mutagenicity

Copper(II) chloride was found to be inactive in the *rec*-assay with *Bacillus subtilis* (Nishioka, 1975; Kanematsu *et al*., 1980).

Copper(II) chloride was also tested for its ability to affect the accuracy of DNA synthesis *in vitro* (Sirover and Loeb, 1976). A copper concentration of 0.08 mM increased the error frequency by more than 30 percent. Hoffman and Niyogi (1977) went on to show that copper(II) chloride stimulated chain initiation of RNA synthesis at a concentration of (2.0 mM/l) that inhibited overall RNA synthesis. The effect of copper(II) chloride was examined using both calf thymus DNA and phage T4 DNA were used as templates. Loeb *et al*. (1978) more recently found that Cu^{2+} increased the misincorporation of bases into synthetic polynucleotides, which indicates that copper may increase errors in the *in vivo* replication of DNA.

(6) Teratogenicity

The teratogenic potential of cupric chloride was evaluated by administration to developing chick embryos (Verett *et al*., 1980). No teratogenic effects were observed with as much as 12.5 mg/egg, injected via the air cell or via the yolk, at two times, preincubation and 96 hours. An LD_{50} of 0.29 mg/egg was determined for cupric chloride.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

b. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

No information was found in the literature searched.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) chloride were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) chloride as an occupational hazard was found in the literature searched.

G. COPPER(I) CYANIDE

1. Chemical Name: Copper(I) Cyanide

2. Chemical Structure: CuCN

3. Synonyms: Cupricin
   Cuprous cyanide

4. Chemical Abstract Service (CAS) Number: 544-92-3

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   GL7150000

6. Chemical and Physical Properties:

Description:	creamy-whte powder
Molecular Weight:	89.56
Boiling Point:	decomposes
Melting Point:	474.5°C
Vapor Pressure:	---
Solubility:	practically insoluble in water, alcohol and cold dil. acids; soluble in alkali cyanide solutions and ammonium hydroxide
Specific Gravity:	2.92
Stability:	---

7. Production

Data available from the U.S. EPA (1980) regarding producers of copper(I) cyanide and production volumes are presented in Table 12.

8. Use

Copper(I) cyanide is mainly used in electroplating baths for coating iron with copper (Winter et al., 1965), for coating zinc and aluminum die castings, and in electroplating of brass and other alloys (Lowenheim, 1979).

It is occasionally used as an insecticide or fungicide, as an antifouling agent in marine paints, as an intermediate in organic reactions to introduce a cyanide group, and as a catalyst in polymerization reactions (Winter et al., 1965).

Table 12. Producers of Copper(I) Cyanide and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
E.I. duPont de Nemours		
LaPlace, LA	Manufacturer-Not Distributed	0.1-1 million lb
Niagara Falls, NY	Manufacturer-Not Distributed	1-10 million lb
Victoria, TX	Manufacturer-Not Distributed	0.1-1 million lb
CP Chemicals		
Sewaren, NJ	Manufacturer	confidential
Nissho-Iwai Amer. Corp.		
New York City, NY	Importer	1-10 million lb
Graymor Chem.		
Pine Brook, NJ	Improter	10-200 thousand lb
Alloy Chem.		
New York City, NY	Importer	0.1-1 million lb
Conray Chem.		
Rockville Centre, NY	Importer	0.1-1 million lb
ICI Americas		
Wilmington, DE	Importer	0.1-1 million lb
Calabrian Int. Corp.		
New York City, NY	Importer	none

9. Manufacturers and Distributors

The manufacturers are listed in Table 12.

Distributors include (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Alloy Chem.
Anachemia Chem.
Apache Chem.
Ashland Chem.
Atomergic Chemetals
J.T. Baker Chem.
Calabrian International
Chem Services
Conray Chem.
EM Lab
Enthone Div.
Fisher Sci.
Gallard-Schlesinger
Graymor Chem.
C.P. Hall Co.
Harshaw Chem.
J.F. Henry
ICI Americas
ICN/K and K
IMC Corp.
Kraft Chem.
LaPine Sci.
M and T Chem.
MCB Reagents
McKesson Chem.
Noah Chem.
Orion Chem.
Pacific Gateway
Pfaltz and Bauer
Philipp Bros. Chem.
Thompson-Hayward Chem.
Tridom Chem.
Joseph Turner and Co.
United Mineral and Chem.
Wego General Trading
Worth Chem.
Kum Yang Co.

10. Manufacturing Processes

Copper(I) cyanide is produced via a precipitation reaction process (Winter et al., 1965); see Figure 2 in Section II of this report for a general flow diagram. The precipitation can be accomplished by adding potassium cyanide to a copper sulfate solution and converting the copper(II) cyanide precipitate to copper(I) cyanide by boiling or drying. Alternatively, scrap copper can be leached with ammonium carbonate solution and sodium cyanide is added to precipitate the copper(I) cyanide. Other methods also involve production of a cuprous salt solution and addition of a soluble cyanide solution.

11. Impurities or Additives

No information was found in the literature searched.

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 16,578 workers are potentially exposed to copper(I) cyanide.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(I) cyanide were not found in the literature searched.

14. Biological Effects

No information on the biological effects of copper(I) cyanide was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(I) cyanide were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(I) cyanide as an occupational hazard was found in the literature searched.

H. COPPER(II) 2-ETHYLHEXANOATE

1. Chemical Name: Copper(II) 2-ethylhexanoate

2. Chemical Structure: $C_4(C_8H_{16}O_2)_2$

3. Synonyms: Copper(II) 2-ethylhexaoate
Copper(II) octoate
Copper(II) octaonate
Cupric 2-ethylhexanoate
Hexanoic acid, 2-ethyl, copper(2+)salt
Octanoic acid, copper salt

4. Chemical Abstract Service (CAS) Number: 149-11-1
22221-10-9
20543-04-8

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

Not listed

6. Chemical and Physical Properties:

Description: ---
Molecular Weight: 351.96
Boiling Point: ---
Melting Point: ---
Vapor Pressure: ---
Solubility: ---
Specific Gravity: ---
Stability: ---

7. Production

Data available from the U.S. EPA (1980) regarding producers of copper(II) 2-ethylhexanoate and production volumes are presented in Table 13.

8. Use

Copper 2-ethylhexanoate is used as a paint, varnish, and ink drier (Bradley, 1975).

9. Manufacturers and Distributors

The manufactuers are listed in Table 13. Interstab Chemicals is also listed as a manufacturer (USTC, 1980).

Table 13. Producers of Copper(II) 2-Ethylhexanoate and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
		CAS No. 22221-10-9
Ferro Chem. Div. Bedford, OH	Manufactuer	under 1000 lb
Tenneco Chem. Elizabeth, NJ	Manufacturer	0.1-1 million lb
Long Beach, CA	Manufacturer	10-100 thousand lb
The Shepherd Chem. Cincinnati, OH	Manufacturer	confidential
Mooney Chem. Franklin, PA	Manufacturer	confidential
		CAS No. 149-11-1
Englehard Indust. East Neward, NJ	Manufacturer	none
Plant Site Not on File	---	confidential
		CAS No. 20543-04-8
Troy Chem. Newark, NJ	Manufacturer	confidential

In addition to the manufacturers, the distributors include (Chem Sources--USA, 1980):

Orion Chem.
Reliable Chem.

10. Manufacturing Processes

Figure 3 in Section II of this report outlines the general manufacturing scheme. The fatty acid, 2-ethylhexanoic acid, is reacted with sodium hydroxide solution to form the soluble sodium 2-ethylhexanoate. This is reacted with a copper sulfate solution which precipitates the copper 2-ethylhexanoate.

11. Impurities or Additives

No information was found in the literature searched.

12. Occupational Exposure

The National Occupational Hazard Survey does not provide an estimate of the number of workers who are potentially exposed to copper(II) 2-ethylhexanoate.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) 2-ethylhexanoate were not found in the literature searched.

14. Biological Effects

No information on the biological effects of copper(II) 2-ethylhexanoate was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) 2-ethylhexanoate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) 2-ethylhexanoate as an occupational hazard was found in the literature searched.

I. COPPER(II) HYDROXIDE

1. Chemical Name: Copper(II) Hydroxide

2. Chemical Structure: $Cu(OH)_2$

3. Synonyms: Copper hydrate
   Cupric hydroxide
   Hydrated copper oxide
   Kocide

4. Chemical Abstract Service (CAS) Number: 20427-59-2

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number: GL7600000

6. Chemical and Physical Properties:

Description:	blue powder to blue gel
Molecular Weight:	97.56
Boiling Point:	**decomposes**
Melting Point:	**decomposes**
Vapor Pressure:	---
Solubility:	insoluble in water; soluble in acids and ammonium hydroxide
Specific Gravity:	3.368
Stability:	---

7. Production

Data available from the U.S. EPA (1980) regarding producers of copper(II) hydroxide and production volumes are presented in Table 14.

Annual production of copper(II) hydroxide is on the order of one million pounds (SRC Estimate).

8. Use

A major use of copper(II) hydroxide is as a fungicide; in 1975 about 0.4 million pounds were consumed for this purpose (Ayers and Johnson, 1976). Other uses include applications in antifouling marine paints, in the cuprammonium process for rayon manufacture, as a nylon stabilizer, as a feed additive, as a dyeing mordant, in production of other copper salts, in staining

Table 14. Producers of Copper(II) Hydroxide and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
Engelhard Indust. Newark, NJ	Manufacturer	1-10 thousand lb
Kocide Chemical Houston, TX	Manufacturer	confidential
Cities Services Co. Copperhill, TN	Manufacturer	confidential
The Shepherd Chem. Cincinnati, OH	Manufacturer	confidential
Tower Chemical Clermont, Fl	Manufacturer	confidential
CP Chemical Sewaren, NJ	Manufacturer	confidential
Chemical-Metal Industries Baltimore, MD	Manufacturer	0.1-1 million lb
Carpenter Tech. Corp. Reading, PA	Manufacturer	10-100 thousand lb
United Catalysts Louisville, KY	Manufacturer	2-20 thousand lb
Learonal Inc. Freeport, NY	Manufacturer	under 1000 lb

paper, in the preparation of Schweitzer's reagents, and in catalysts (Kust, 1979; Winter et al., 1965; Hawley, 1977; The Merck Index, 1976).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers

CP Chemicals	Sewaren, NJ
Imperial West Chem.	Antioch, CA
Kocide Chem.	Houston, TX

Other manufacturers are listed in Table 14.

In addition to the manufacturers, the distributors include (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers'Guide Issue, 1980; Chem Sources--USA, 1980):

Anachemia Chem.
Apache Chem.
Aran Isles Chem.
Atomergic Chemetals
Bodman Chem.
Chempar Chem.
Faesy and Besthoff
Gallard-Schelsinger
Great Western Inorganics
ICN/K and K
Noah Chem.
Pacific Gateway
Pfaltz and Bauer
Philipp Bros. chem.
Southern Calif. Chem.
Sylvan Chem.
Synmet Inc.
Tridom Chem.

10. Manufacturing Processes

Copper(II) hydroxide is manufactured by several different methods (Kust, 1979; Winter et al., 1965). One process consists of adding ammonia to a copper sulfate solution to form a cuprous ammonium sulfate solution. This solution is filtered to remove impurities and sodium hydroxide is added to precipitate the copper hydroxide. It is filtered, washed, and dried; Figure 2 in Section II of this report outlines a general process scheme. Copper hydroxide prepared by this method is used in the cuprammonium rayon process and in the preparation of other copper salts, especially the soaps.

In another process, a solution of trisodium phosphate and copper sulfate act as the reaction medium. Solutions of sodium hydroxide and copper sulfate are simultaneously charged to the reactor and the copper hydroxide is again precipitated and finished as described above. Alternatively, a solution of trisodium phosphate and sodium sulfate is electrolyzed with a copper anode to form copper hydroxide. The copper hydroxide formed via these processes is used in fungicides and paints.

11. Impurities or Additives

The following is one manufacturers typical analysis of a copper(II) hydroxide product (C.P. Chemicals, undated):

Cupric hydroxide $Cu(OH)_2$	97% (min)
Copper as Cu	63%
Acetic acid Insoluble	0.2% (max)
Naphthenic acid Insoluble	approx. 2.0%
Sulfur	less than 0.18%
Chlorides as Cl	less than 0.20%

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 22,840 workers are potentially exposed to copper(II) hydroxide.

13. Control Tecnology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) hydroxide were not found in the literature searched.

14. Biological Effects

The only information on the biological effects of copper(II) hydroxide found in the literature searched is a cytological study. In an investigation of the effect of copper(II) hydroxide (200 mg/kg body weight administered by intraperitoneal injection) on the MTK-sarcoma III rat ascites tumor _in vivo_, Kimura and Makino (1963) reported the development of mitotic abnormalities, as evidenced by chromatic aggregation and stickiness of chromosomes.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) hydroxide were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

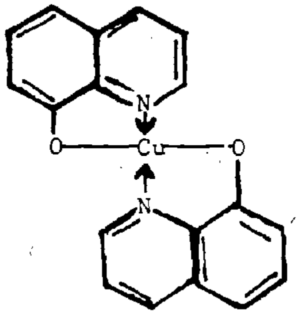
18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) hydroxide as an occupational hazard was found in the literature searched.

J. COPPER(II) 8-HYDROXYQUINOLATE

1. <u>Chemical Name</u>: Copper(II) 8-hydroxyquinolate

2. <u>Chemical Structure</u>:



3. Synonyms:
   - Bioquin
   - Bis(8-quinoline)copper
   - Bis(8-quinolinolato-Ni,08)copper
   - Cellu-quin
   - Copper 8
   - Copper 8-quinolinol
   - Copper 8-quinolinolate
   - Copper oxinate
   - Copper oxine
   - Copper oxyquinolate
   - Copper oxyquinoline
   - Copper quinolate
   - Copper quinolinolate
   - Cunilate 2472
   - Cupric 8-hydroxyquinolate
   - Cuproquin
   - Dormycin
   - Milmerl
   - Oxine copper
   - Quindex
   - Quinolate
   - Quinondo
   - Tomo-oxiran

4. <u>Chemical Abstract Service (CAS) Number</u>: 10380-28-6

5. <u>Registry of Toxic Effects of Chemical Substances (RTECS) Number</u>:

   VC5250000

6. <u>Chemical and Physical Properties</u>:

Description:	greenish-yellow crystalline powder
Molecular Weight:	351.86
Boiling Point:	---
Melting Point:	---
Vapor Pressure:	---
Solubility:	Insoluble in water, ethanol, and most common organic solvents; somewhat soluble in pyridine, quinoline, and weak acids; soluble in strong acids
Specific Gravity:	---
Stability:	---

7. Production

Annual production is about 100 thousand pounds (IARC, 1977).

Data available from the U.S. EPA (1980) regarding producers of copper 8-hydroxyquinolate and production volumes are presented in Table 15.

8. Use

Copper 8-hydroxyquinolate is a fungicide used in the treatment of textiles, as an ingredient of paints, in wood and paper preservation and in agriculture (Turner, 1966).

According to IARC (1977), about 75% of the copper 8-hydroxyquinolate used in the US is used in the treatment of textiles such as fabric, rope, thread webbing, and cordage, and fishing nets. Trotz and Pitts (1981) state that textile uses are almost exclusively in military applications such as tents, tarpaulins, and sandbags; the high-concentration levels required, 0.1-1.0%, and the intense green color make then unsuitable for most consumer products. Consumption in 1978 was about 100 thousand pounds (Trotz and Pitts, 1981).

According to Trotz and Pitts (1981), a small amount of copper 8-hydroxyquinolate is used in wood preservation. However, Ayers and Johnson (1976) have listed copper 8-hydroxyquinolate's consumption in wood preservatives in 1975 as 100 thousand pounds. Types of wood applications include containers which are in contact with food products such as beverage boxes, field crates, hampers, pallets, and other wood containers for fruits and vegetables.

Minor uses include fungicidal applications in green paints, PVC plastics, paper, and ornamental crops (IARC, 1977; Trotz and Pitts, 1981).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers:

Kocide Chem.	Houston, TX
Southland Corp-Fine Chem.	Great Meadows, NJ
Tenneco Chem.	Elizabeth, NJ
Troy Chem.	Newark, NJ

Table 15. Producers of Copper(II) 8-Hydroxyquinolate and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
Kocide Chemical		
Houston, TX	Manufacturer	confidential
Ashland Chemical		
Great Meadows, NJ	Manufacturer	1-10 thousand lb
Dublin, OH	Importer	10-100 thousand lb
Plant Site Not on File	---	10-100 thousand lb
Plant Site Not on File	---	10-100 thousand lb

Other distributors include (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

- CP Chem.
- ICD LGroup
- ICN/K and K
- Koppers Co.
- Pfaltz and Bauer
- Reliable
- Seymour Chem.
- Tanabe U.S.A.
- Thiokol/Ventron

10. Manufacturing Processes

Copper 8-hydroxyquinolinate is manufactured by the precipitation of solutions of copper salts with 8-hydroxyquinoline (Spencer, 1968). Figure 2 in Section II of this report outlines a general manufacturing scheme.

11. Impurities or Additives

From IARC (1977):

> "Copper 8-hydroxyquinoline is available in the US in liquid concentrates containing 0.25 to 10.0%, as pastes containing 5.0 to 30.0%, as solids containing 5.0 to 10.0% and as ready-to-use liquids containing 0.25 to 1.5% of the pure chemical, and as a 5.0% liquid concentrate in combination with 17.6% pentachlorophenol and 2.5% tetrachlorophenol. It is also used in combination with zinc petroleum sulphonate (US Environmental Protection Agency, 1973).
>
> A typical grade of this chemical is also available in the US and Japan. Typical specifications are for 99% purity, a maximum of 10 mg/kg free copper and a maximum particle size of 5 microns for the granular form. Free copper and free 8-hydroxyquinoline are impurities."

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 9,552 workers are potentially exposed to chemical.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) 8-hydroxyquinolate were not found in the literature searched.

14. Biological Effects

a. Animal Studies

(1) Acute Exposures

An intraperitoneal LD_{50} value of 67 mg/kg (95% confidence interval of 56-80 mg/kg) in Swiss albino mice was reported for a copper(II) chelate of 8-quinolinol (Berstein et al., 1963). Female mice were generally more sensitive than males in that the onset of symptoms and mortality occurred earlier.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

(4) Carcinogenicity

Two groups of 18 male and 18 female [(C57BL/6xC3H/Anf)F_1 and (C57BL/6xAKR)F_1] mice received 1000 mg/kg body weight copper 8-hydrowyquinoline daily from age one week to four weeks in five percent gelatine by gavage (NTIS, 1968). Administration of 2800 mg/kg diet followed the gavage until the mice were 78 weeks of age. There was no increase in tumor incidences over control ($P>0.05$). Two more groups of 18 male and 18 female (same strains) mice received a single subcutaneous injection (1000 mg/kg body weight) of copper 8-hydroxyquinoline at age 28 days. An observation period followed until the mice were 78 weeks of age. One male strain manifested an increased incidence of reticulum-cell sarcomas over controls (6/17 compared to 8/141,

$P<0.001$) while no tumors were seen in the second strain. Both female strains developed some reticulum-cell sarcomas: 1/18 and 3/18 compared to the controls (1/154 and 5/157). In a review by IARC (1977) it was stated that no evaluation of the carcinogenicity of copper 8-hydroxyquinoline could be made on the data available.

In another study, 20 mice (strain unspecified) received 39 subcutaneous injections of 0.1 mg copper 8-hydroxyquinoline at weekly intervals for 10 months (Haddow and Horning, 1960). Only one tumor, a pleomorphic sarcoma, developed in the 14 surviving animals.

(5) Mutagenicity

No information was found in the literature searched.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

b. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

No information was found in the literature searched.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) 8-hydroxyquinolate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

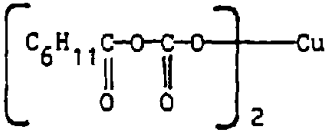
18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) 8-hydroxyquinolate as an occupational hazard was found in the literature searched.

K. COPPER(II) NAPHTHENATE

1. Chemical Name: Copper(II) Naphthenate

2. Chemical Structure:



$$\left[C_6H_{11}\underset{\underset{O}{\|}}{C}-O-\underset{\underset{O}{\|}}{C}-O\right]_2-Cu$$

(variable)

3. Synonyms: Copper Urersol
Cuprinol
Naphthenic acid, copper(2+)salt
Nuodex
Wittcox C

4. Chemical Abstract Service (CAS) Number: 1338-02-9

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

QK9100000

6. Chemical and Physical Properties:

Description:	green-blue solid
Molecular Weight:	405.86 (variable)
Boiling Point:	---
Melting Point:	---
Vapor Pressure:	---
Solubility:	Insoluble in water; soluble in gasoline, benzene, mineral oil distillates, and common organic solvents
Specific Gravity:	---
Stability:	commercial product is flammable

7. Production

Production of copper naphthenate in recent years is as follows (USITC, 1977, 1978, 1979, 1980):

Year	Production (in millions of pounds)
1979	1.606
1978	1.188
1977	1.127
1976	0.906

Data available from the U.S. EPA (1980) regarding producers of copper naphthenate and production volumes are presented in Table 16.

8. Use

Copper naphthenate has a variety of fungicidal and preservative applications. It is used in the mildew proofing of textiles, and for this application, it is used almost exclusively for military uses such as tents, tarpaulins, and sandbangs (Trotz and Pitts, 1981). The high concentration levels required in these military applications, 0.1-1%, and the intense green color makes it unsuitable for most consumer products. In 1978, consumption for this use was about 100 thousand pounds.

Ayers and Johnson (1976), listed copper naphthenate consumption in wood preservation applications in 1975 as 900 thousand pounds.

Copper naphthenate is also used in antifouling paints, to prevent deposits in furnaces and burners fired with coal or heavy oil, and in PVC plastics (Buono and Feldman, 1979; Hawley, 1977; Trotz and Pitts, 1981).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers:

Interstab Chem.	New Brunswick, NJ
Mooney Chem.	Franklin, PA
Tenneco Chem.	Elizabeth, NJ
Triangle Chem.	Macon, GA
Troy Chem.	Newark, NJ
Witco Chem.	Clearing, IL
	Lynwood, CA

In addition to the manufactuers, the distributors include (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

CP Chem.
Fungicides Inc.
D.F. Goldsmith Chem. and Metals
ICD Group
ICN/K and K
Koppers Co.
Mide Chem.
Orion Chem.
Pfaltz and Bauer
Reliable Chem.
Signo Trading
Sylvan Chem.

Table 16. Producers of Copper(II) Naphthenate and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
Ferro Chem. Div. Bedford, OH	Manufacturer	10-100 thousand lb
Tenneco Chem. Long Beach, CA	Manufacturer	under 1000 lb
Pennwalt Corp. Homer, NY	Manufacturer	under 100 lb
Mooney Chem. Franklin, PA	Manufacturer	confidential
Witco Chem. Lynwood, CA	Manufacturer	confidential
Plant Site Not on File	Manufacturer	10-100 thousand lb
Plant Site Not on File	Manufacturer	0.1-1 million lb

10. Manufacturing Processes

Copper naphthenate is manufactured by the reaction of naphthenine acids with sodium hydroxide followed by addition of a copper sulfate (or carbonate) solution to precipitate the copper naphthenate (Whitaker, 1965; Spencer, 1968). Figure 3 in Section II of this report depicts the general process operations.

Copper naphthenate can also be produced by passing air as a catalyst at a rapid rate through a mixture of copper metal and naphthenic acids maintained at 200°C (Whitaker, 1965).

11. Impurities or Additives

Copper naphthenate is sold commercially in a solution containing 8% copper; the solvent can be petroleum distillates.

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 24,864 workers are potentially exposed to copper(II) naphthenate.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) naphthenate were not found in the literature searched.

14. Biological Effects

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) naphthenate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) naphthenate as an occupational hazard was found in the literature searched.

L. COPPER(II) NITRATE

1. **Chemical Name**: Copper (II) Nitrate

2. **Chemical Structure**: $Cu(NO_3)_2$

3. **Synonyms**: Copper dinitrate
   Cupric dinitrate
   Cupric nitrate
   Nitric acid, copper (II) salt

4. **Chemical Abstracts Service (CAS) Number**: 3251-23-8
   10031-43-3 (trihydrate)

5. **Registry of Toxic Effects of Chemical Substances (RTECS) Number**:

   GL7875000

6. **Chemical and Physical Properties**:

Description:	blue crystal; deliquescent
Molecular Weight:	187.56 (anhydrous) 241.60 (trihydrate)
Boiling Point:	---
Melting Point:	114.5°C (trihydrate)
Vapor Pressure:	---
Solubility:	137.8 g/100 g water at 0°C (trihydrate); soluble in alcohol
Specific Gravity:	2.05
Stability:	---

7. **Production**

The copper nitrate of commerce is cupric nitrate trihydrate, $Cu(NO_3)_2 \cdot 3H_2O$. Data available from the U.S. EPA (1980) regarding producers of copper(II) nitrate and production volumes are presented in Table 17. Annual production is judged to be in excess of one million pounds (SRC Estimate).

8. **Use**

Copper(II) nitrate has wide applications (Kust, 1979). It is used in light-sensitive reproductive papers, as a ceramic color, as a mordant and oxidant in textile dyeing and printing, as a reagent for burnishing iron, as a

Table 17. Producers of Copper(II) Nitrate and Production Ranges (U.S. EPA, 1980)

Producer and Location	Type of Production	1977 Production Range
Mineral Research and Development Corp. Concord, NC	Manufacturer	confidential
McGean Chemical Co. Cleveland, OH	Manufacturer	1 to 10 thousand lb
Allied Chemical Corp. Buffalo, NY	Manufacturer	0.1 to 1 million lb
Katalco Corp. Chicago, IL	Manufacturer Produced Site Limited	confidential
Engelhard Industries Div. Newark, NJ	Manufacturer	10 to 100 thousandlb
Union Carbide Corp. Ambler, PA	Manufacturer	under 1000 lb
St. Joseph, MO	Manufacturer	under 1000 lb
Ferndale, MI	Manufacturer	under 1000 lb
United Catalysts, Inc. Louisville, KY	Manufacturer	10 to 100 thousand lb
Louisville, KY	Manufacturer	1 to 10 thousand lb
The Shepherd Chemical Co. Cincinnati, OH	Manufacturer	confidential
J.T. Baker Chemical Co. Phillipsburg, NJ	Manufacturer	10 to 100 thousand lb
The Harshaw Chemical Co. Elyria, OH	Manufacturer	10 to 100 thousand lb
Gulf Chemical Metallurgical Ironton, OH	Manufacturer	0.1 to 1 million lb

Table 17. Producers of Copper(II) Nitrate and Production Ranges (U.S. EPA, 1980) (Cont'd)

Producer and Location	Type of Production	1977 Production Range
CP Chemicals Inc. Sewaren, NJ Sumter, SC	Manufacturer	confidential
J.E. Halma Co. Lodi, NJ	Importer/ Small Manufacturer	confidential
United Mineral and Chemical Co. New York City, NY	Importer	under 1000 lb
American Hoescht Corp. Bridgewater, NJ	Importer	confidential
Calabrian International Corp. New York City, NY	Importer	zero

wood preservative agent, as a catalyst for numerous organic reactions, as a catalyst component in solid rocket fuel, as a pyrotechnic ingredient, as a flotation agent for cinnabar, as a drilling mud dispersant, as a corrosion inhibitor, and to reduce carcinogenic gases in tobacco smoke and in sarcoma inhibition (Kust, 1979; Winter _et al_, 1965). It is also used in electro-plating (Lawler, 1977) and in paints, varnishes, and enamels (Hawley, 1977).

A breakdown of the percentages of the total amount of copper(II) nitrate produced that are used in various applications is not available.

9. _Manufacturers and Distributors_

SRI International (1980) lists the following as manufacturers of cupric nitrate:

Allied Chem. Corp.	Buffalo, NY
Chems. Co.	Marcus Hook, PA
Associated Metals and Minerals Corp.	
Gulf Chem. and Metallurgical Co., div.	Ironton, OH
C.P. Chems., Inc.	Sumter, SC
Kocide Chem. Co.	Houston, TX
McGean Chem. Co., Inc.	Cleveland, OH
Mineral Research and Dev. Corp.	Concord, NC
Richardson-Merrell, Inc.	
J.T. Baker Chem. Co., subsid.	Phillipsburg, NJ
The Shepherd Chem. Co.	Cincinnati, OH
Southern California Chem. Co., Inc.	Bayonne, NJ Santa Fe Springs, CA Union, IL
United Catalysts Inc.	Louisville, KY

Data available from the U.S. EPA (1980) regarding producers of copper(II) nitrate and production volumes are presented in Table 17.

In addition to the manufacturers, the distributors include (_1980-81 OPD Chemical Buyers Directory_, 1980; _Chemical Week: 1981 Buyers' Guide Issue_, 1980; _Chem Sources--USA_, 1980):

ARS Chemical Corp.
Alfa Prod.
American Hoescht Corp.
Gallard-Schelsinger
Great Western Inorganics
Hetako Chem.

Anachemia Chem.
Apache Chem.
Atomergic Chemetals
Bio-Clinical Lab.
Bodman Chem.
Chem Services
Covinter, Inc.
Delamar
EM Lab
Fisher Sci.
LaPine Sci.
MCB Reagents
Mallinckrodt
Mechema Ltd.
Noah Chem.
Pacific Gateway
Pfaltz and Bauer
Philipp Bros. Chem.
Reliable Chem.
Spex Ind.
Tridom Chem.

10. Manufacturing Processes

Copper nitrate solutions can be prepared by dissolving cupric oxide, hydroxide, or carbonate, or copper metal in nitric acid. Oxides of nitrogen are evolved in the reaction with copper metal as shown by the following reactions:

$$3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O \qquad (1)$$

$$Cu + 4HNO_3 \longrightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2 \qquad (2)$$

Equation 1 is favored by dilute acid and low temperature. No oxides of nitrogen are evolved in the reaction with copper oxide, hydroxide, or carbonate. The decision as to the use of cupric oxide, for instance, or copper depends upon the cost of the different raw materials and the means of using or disposing of the nitrogen fumes (Winter et al., 1965).

The copper nitrate solution which has been produced can then be crystal-lized (or evaporated) to form the solid product; the usual washing and drying of the solid product followed by grinding or pulverizing completes the production process. Figure 9 outlines the process operations.

11. Impurities or Additives

Cupric nitrate may be supplied commercially as a 41% or 50% solution.

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 70 workers are potentially exposed to chemical.

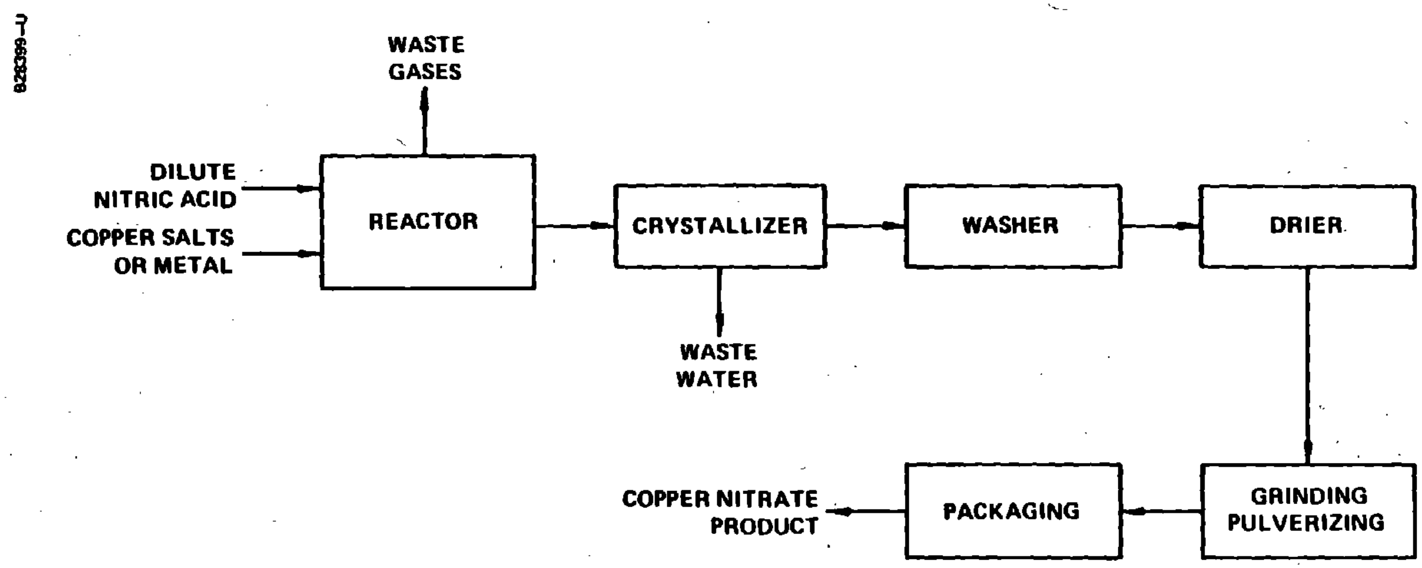


Figure 9. Copper Nitrate Manufacture Operations

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) nitrate were not found in the literature searched.

14. Biological Effects

a. Animal Studies

(1) Acute Exposures

Information on the acute toxic effects of copper(II) nitrate is scarce but Smyth *et al*. (1969) did report an oral LD_{50} of 940 mg/kg in male Wistar rats.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

(4) Carcinogenicity

No information was found in the literature searched.

(5) Mutagenicity

In an investigation of the cytological effects of copper(II) nitrate (600 mg/kg body weight administered intraperitoneally) on the MTK-sarcoma III rat ascite tumor *in vivo*, Kimura and Makino (1963) reported the development of mitotic abnormalities, as evidenced by chromatic aggregation, karyorrhexis, and stickiness of chromosomes.

Loeb *et al*. (1978) recently found that Cu^{2+} increased the misincorporation of bases into synthetic polynucleotides, which indicates that copper may increase errors in the *in vivo* replication of DNA.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

b. Human Studies

(1) Pharmacokinetics

In an attempt to clarify certain aspects of Wilson's disease, Bearn and Kunkel (1955) examined the distribution and excretion of intravenously injected radioactive Cu^{64} (in the form of copper acetate or copper nitrate) in normal subjects and patients with Wilson's disease. An extremely rapid decrease, followed by a larger increase, in serum radioactively was observed in normal subjects. In patients with Wilson's disease, the decrease in serum radioactivity was slower and was not followed by a subsequent increase. It was demonstrated in normal subjects that the rise in serum radioactivity was due to its incorporation into ceruloplasmin and, since this protein is deficient in Wilson's diesease, no increase in serum radioactivity was noted in these patients. Excess administered copper associated with serum albumin persisted much longer in patients with Wilson's disease than in control subjects. In Wilson's disease subjects, total radioactivity excretion in the urine was greater than, and fecal excretion was less than, that found in normal subjects.

(2) Health Effects

No information was found in the literature searched.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are currently being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) nitrate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

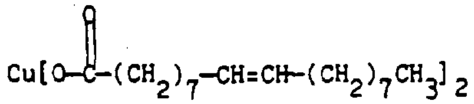
18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) nitrate as an occupational hazard was found in the literature searched.

M. COPPER(II) OLEATE

1. Chemical Name: Copper(II) Oleate

2. Chemical Structure:



$$\mathrm{Cu[O{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}(CH_2)_7{-}CH{=}CH{-}(CH_2)_7CH_3]_2}$$

3. Synonyms: Cupric oleate
   9-octadecenoic acid (Z)-, copper (2+) salt

4. Chemical Abstract Service (CAS) Number: 1120-44-1
   10402-16-1

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   Not listed

6. Chemical and Physical Properties:

Description:	brown to bluish-green mass
Molecular Weight:	626.43
Boiling Point:	---
Melting Point:	---
Vapor Pressure	---
Solubility:	insoluble in water; soluble in ether; slightly soluble in alcohol
Specific Gravity:	---
Stability:	combustible

7. Production

In 1975, about 200 thousand pounds were consumed in fungicidal applications (Ayers and Johnson, 1976).

Data available from the U.S. EPA (1980) regarding producers of copper oleate and production volumes are presented in Table 18.

8. Uses

Copper oleate's major use is in fungicidal applications. In 1975, 100 thousand pounds were used for deciduous fruits and 100 thousand pounds

Table 18. Producers of Copper Oleate and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
Witco Chem. Corp. Lynwood, CA	Manufacturer	confidential
Troy Chem. Corp. Newark, NJ	Manufacturer	confidential
Pennwalt Corp. Homer, NY	Manufactuer	under 1000 lb

were used for field crops other than vegetables and soybeans (Ayers and Johnson, 1976).

Other uses include preserving fish nets and marine lines, as an ore flotation agent, in medicines, in antifouling paints, as an emulsifier and dispersing agent, as an antioxidant in lubricating oils, as a stabilizer for amide polymers, as a catalyst, and as an oil combustion improver (Hawley, 1977; Kust, 1979; The Merck Index, 1976).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers:

Troy Chem.	Newark, NJ
Witco Chem.	Clearing, IL Lynwood, CA

Other distributors include (1980-81 OPD Chemical Buyers Directory, 1980; Chem Sources--USA, 1980):

Sattva Trading
ICN/K and K
Pfaltz and Bauer

10. Manufacturing Processes

Copper oleate is made by the interaction of copper sulfate and sodium oleate (Hawley, 1977). Figure 3 in Section II of this report outlines the general manufacturing scheme. The sodium oleate is formed by adding sodium hydroxide solution to oleic acid. Addition of copper sulfate causes the copper oleate to precipitate.

11. Additives and Impurities

Copper oleate is available commercially as a solid and as a solution.

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 23,537 workers are potentially exposed to copper(II) oleate.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) oleate were not found in the literature searched.

14. Biological Effects

No information on the biological effects of copper(II) oleate was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) oleate were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) oleate as an occupational hazard was found in the literature searched.

N. COPPER(I) OXIDE

1. Chemical Name: Copper(I) Oxide

2. Chemical Structure: Cu_2O

3. Synonyms: Brown copper oxide
   C.I. 77402
   Copox
   Copper hemioxide
   Copper oxide, red
   Copper protoxide
   Copper sandoz
   Copper sardez
   Copper suboxide
   Cupramar
   Cuprite
   Cuprocide
   Cuprous oxide
   Dicapper monoxide
   Fungimar
   Kuprite
   Nordox
   Oleocuivve
   Perecot
   Perenox
   Yellow Cuprocide

4. Chemical Abstracts Service (CAS) Number: 1317-39-1

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   GL8050000

6. Chemical and Physical Properties:

Description:	reddish-brown crystalline powder
Boiling Point:	1800°C
Melting Point:	1210°C
Vapor Pressure:	---
Solubility:	insoluble in water, organic solvents, and alcohol; soluble in dilute mineral acids, aqueous ammonia solutions, hydrochloric acid; slightly soluble in nitric acid
Specific Gravity:	5.75-6.09
Stability:	---

7. Production

The following production data are available for copper(I) oxide (U.S. Dept. of Commerce, 1980):

Year	Production (in Millions of Pounds)
1979	8.33
1978	7.06
1977	6.92
1976	9.23
1975	4.77

Data available from the U.S. EPA (1980) regarding producers of copper(I) oxide and production volumes are presented in Table 19.

8. Use

Copper(I) oxide is used as a catalyst for chemical processes (such as in the oxidation of carbon monoxide and oxides of nitrogen in exhaust gases, in the oxidation of olefins, and in the chlorination of ethylene), as a fungicide for many crops and seed treatments, and as an antioxidant in lubricants. It is also used as an antiseptic agent in the treatment of fish nets, as an important pigment in antifouling points for marine use, as a red pigment used in making ruby-red glass and semiconducting porcelain glaze on ceramics, and in the purification of helium (Kust, 1979; Winter *et al*., 1965).

A breakdown of the percentages of the total amount of copper(I) oxide produced that are used in various applications is not available.

In 1975, about 0.4 million pounds of the copper(I) oxide produced were consumed for fungicidal uses (Ayers and Johnson, 1976).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturers:

American Chemet Corp.	East Helena, MT
Belmont Metals Inc.	Brooklyn, NY
Copper Chem. Corp.	Pawtucket, RI

Table 19. Producers of Copper(I) Oxide and Production Ranges (U.S. EPA, 1980)

Producer	Type of Production	1977 Production Range
American Chemet Corp.		
East Helena, MT	Manufacturer	confidential
Calsicat Div.		
Eric, PA	Manufacturer	none
United Catalysts		
Louisville, KY	Manufacturer	under 2000 lb
Tower Chemical		
Clermont, FL	Manufacturer	confidential
SCM Corp.		
Hammond, IN	Manufacturer	confidential
Johnstown, PA	Manufacturer	confidential
The Prince Mfg. Co.		
Quincy, IL	Manufacturer	confidential
Quincy, IL	Importer	confidential
Bowmanstown, PA	Importer	confidential
Bowmanstown, PA	Manufacturer	confidential
Handy and Harmon		
Attleboro, MA	Manufacturer	confidential
C.P. Chemicals		
Sewaren, NJ	Manufacturer	confidential
Powder Springs, GA	Manufacturer	confidential
Revelli Chemicals		
Yonkers, NY	Importer	1-10 million lb
Conray Chem.		
Rockville Centre, NY	Importer	none
Calabrian International		
New York City, NY	Importer	confidential
Plant Site Not on File	---	0.1-1 million lb

C.P. Chems., Inc.	Powder Springs, GA Sewaren, NJ
SCM Corp. Chemical/Metallurgical Div. Glidden Metals Group	Hammond, Ind.
Smith Chem. and Color Co. Inc.	Jamaica, NY

Other manufacturers are listed in Table 19.

Additional distributors include the following (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Aldrich Chem.
Alfa Prod.
Anachemia Chem.
Apache Chem.
Atomergic Chemetals
J. T. Baker, Chem.
Bodman Chem.
Calabrian International Corp.
Chem. Services
Conray Chem.
Convinter Inc.
Fehr Bros.
Fisher Sci.
Gallard-Schelsinger
Great Western
The Hall Chem.
ICD Group Inc.
LaPine Sci.
MCB Reagents
Madison Industries, Inc.
Orion Chem.
Pacific Gateway
The Pesses Co.
Pfaltz and Bauer
Revelli Chemicals, Inc.
Southern California Chem.
Spex Indus.
Timac Chem.
United Mineral and Chem. Corp.
Char. A. Wagner Chem.

10. Manufacturing Processes

The industrial manufacturing of copper(I) oxide is usually based on furnace technology or electrolytic methods. Commercially pure (95% Cu_2O) cuprite is prepared by furnace reduction of mixtures of copper oxides with copper; quantities of mixed copper oxides are produced as by-products of the metallurgy of copper refining and fabrication, as a scale from the anodes of copper refineries, from certain wrought copper products after annealing, or from wire in the course of drawing. In order to produce the cuprous oxide product, this material mixture is subjected to a furnace treatment of high temperature (above 1030°C, which is the decomposition temperature of cupric oxide) and finally is cooled quickly in an inert atmosphere, or by quenching in water to prevent reoxidation (Winter et al., 1965; Utter and Tuwiner, 1949). Figure 10 shows this method schematically.

The electrotytic manufacturing methods are used when particle sizes are important, as for pigment and agricultural purposes. An alkaline solution of sodium chloride is the electrolyte. The anodes are composed of refined copper and the cathodes are copper sheet. Cuprous oxide is formed at the anode. The particle size of the product is determined by the temperature, pH, and the time of contact of the deposited oxide with the electrolyte. The finer sizes are yellow, and the coarser deep red; the red forms are preferred for paint and the yellow for fungicides (Utter and Tuwiner, 1949; Winter et al., 1965).

By another method, a floating slag of copper(I) oxide is produced when molten refined copper is blown with air; the molten oxide is cast, crushed, and pulverized. In another method of preparation, copper is leached from ore with an ammonium carbonate solution to form cuprous ammonium carbonate; the ammonia and carbon dioxide are distilled, leaving a mixture of copper oxides that is then treated at 70°C with a low-molecular-weight organic acid such as formic or acetic until the cupric oxide is dissolved; the undissolved cuprous oxide is separated from the liquid portion from which the cupric oxide can be recovered by evaporation and crystallization. A yellow-orange cuprous oxide of 99.4% purity and particle size of 1-10 μ is claimed in a process invented by Rowe. A slurry of cupric hydroxide precipitated from a copper sulfate solution by sodium hydroxide is treated with sulfur dioxide to form a basic cuprous sulfite. By digestion under controlled conditions of acidity and temperature, cuprous oxide is formed. The colloidal particles are filtered off, leaving cupric sulfate solution for recycle. The basic equation for the operation is the following (Winter et al., 1965):

$$3Cu(OH)_2 + SO_2 \longrightarrow Cu_2O + CuSO_4 + 3H_2O$$

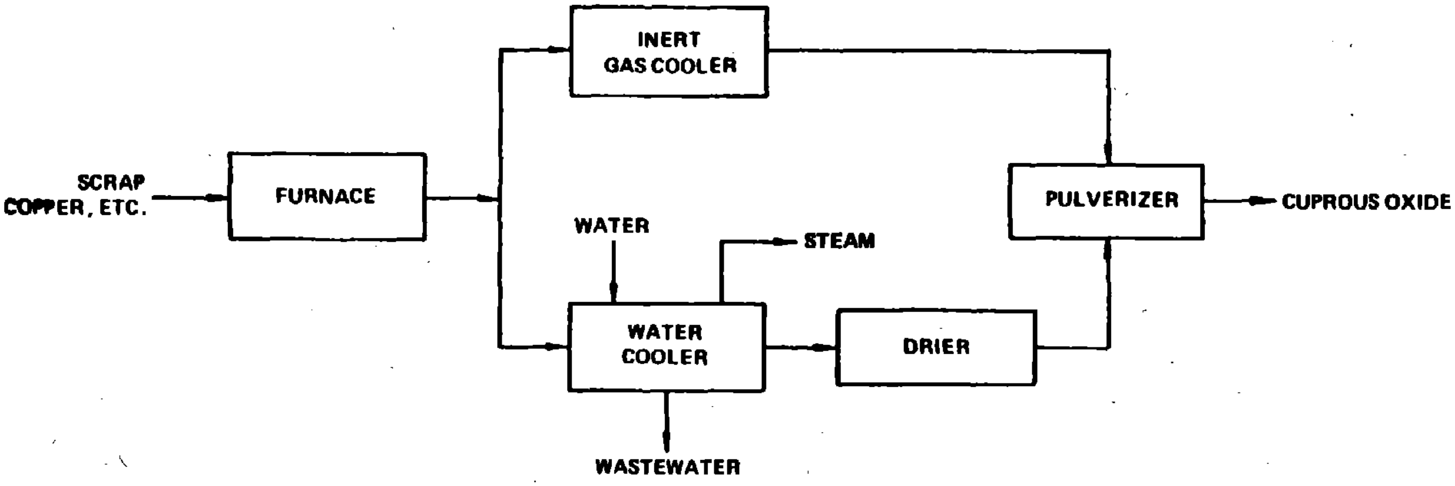


Figure 10. Manufacture of Copper(I) Oxide Via Furnace Reduction

11. Impurities or Additives

Copper(I) oxide is produced commercially in a variety of grades. High-purity grades contain a 97% minimum of Cu_2O. Lower grades contain a mixture of copper(I) and (II) oxides; for example, the typical analysis of a copper oxide 75% material which is marketed is the following (C.P. Chemicals, undated):

Total copper	75%
Cupric oxide	55.0%
Cuprous oxide	29.4%
Iron oxide	3.6%
Metallic copper	5.0%
Limestone	6.6%
Trace compound	0.4%

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 652,013 workers are potentially exposed to copper(I) oxide.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(I) oxide were not found in the literature searched.

14. Biological Effects

A. Animal Studies

(1) Acute Exposures

Information on the acute toxic effects of copper(I) oxide is scarce but Smyth et al. (1969) did report an oral LD_{50} of 470 mg/kg in male Wistar rats.

Batsura (1969) exposed rats to a condensation aerosol of copper oxide (50-80 mg/m^3) for 15, 30, 45, 60 or 180 minutes. Animals exposed for 1 hour or less were sacrified immediately and those exposed for 3 hours were sacrificed at 0, 3, 6, 12, 18, and 24 hours after termination of the experiment. Ultimately, as revealed by electron-microscopic examination, the particles had penetrated through all sections of the air-blood barrier and into the alveolar epithelial cells in animals exposed for three hours. Copper oxide crystals were found in the plasma six-hours after the three-hour exposure had begun. Aerosol dust was also found in the ultrastructures of the proximal nonvoluted tubules.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

(4) Carcinogenicity

No information was found in the literature searched.

(5) Mutagenicity

No information was found in the literature searched.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

B. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

Metal fume fever is most likely caused by exposure to freshly produced copper oxide from fine copper dusts or fumes (McCord, 1960). The illness lasts 24 to 48 hours and is characterized by fever, chills, aching muscles, headache, and a dry mouth and throat.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

No information was found in the literature searched.

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(I) oxide were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(I) oxide as an occupational hazard was found in the literature searched.

O. COPPER(II) OXIDE

1. **Chemical Name**: Copper(II) Oxide

2. **Chemical Structure**: CuO

3. **Synonyms**: C.I. 77403
   C.I. Pigment Black 15
   Copper monoxide
   Copper oxide, black
   Cupric oxide

4. **Chemical Abstracts Service (CAS) Number**: 1317-38-0

5. **Registry of Toxic Effects of Chemical Substances (RTECS) Number**:

   Not listed

6. **Chemical and Physical Properties**:

Description:	brownish-black, amorphous or crystalline powder
Molecular Weight:	79.54
Boiling Point:	decomposes
Melting Point:	1326°C (decomposes in air at 1026°C)
Vapor Pressure:	---
Solubility:	insoluble in water and alcohol; soluble in dilute acids, alkali cyanides, ammonium carbonate solution, ammonia, ammonium chloride and potassium cyanide.
Specific Gravity:	6.3-6.49
Stability:	---

7. **Production**

Data available from the U.S. EPA (1980) regarding producers of copper(II) oxide and production volumes are presented in Table 20.

The following production data are available for copper(I) oxide (MCA, 1971, 1975):

Year	Production (in Millions of Pounds)
1973	6.04
1972	3.71
1968	3.82

Table 20. Producers of Copper(II) Oxide and Production Ranges (U.S. EPA, 1980)

Producer and Location	Type of Production	1977 Production Range
Westmin Corp.		
Quincy, IL	Manufacturer	confidential
American Chemet Corp.		
East Helena, MT	Manufacturer	confidential
Katalco Corp.		
Chicago, IL	Manufacturer	confidential
Engelhard Industries		
Newark, NJ	Manufacturer	2 to 20 thousand lb
Dow Chemical		
Ludington, MI	Manufacturer	10 to 100 thousand lb
Kocide Chemical Corp.		
Houston, TX	Manufacturer	confidential
Monsanto Co.		
St. Louis, MO	Importer	10 to 100 thousand lb
Texas City, TX	Manufacturer	0.1 to 1 million lb
Martinez, CA	Manufacturer	under 1000 lb
Copperweld Bimetallics Div.		
Glassport, PA	Manufacturer	0.1 to 1 million lb
Calsicat Div.		
Erie, PA	Manufacturer	confidential
Valumet Processing Corp.		
Sayreville, NJ	Manufacturer	10 to 100 thousand lb
Union Carbide Corp.	Manufacturer	confidential
Institute, WV	Produced Site Limited	
ARS Chemical Corp.		
Providence, RI	Manufacturer	10 to 100 thousand lb
United Catalysts, Inc.		
Louisville, KY	Manufacturer	1 to 10 thousand lb
Louisville, KY	Manufacturer	0.1 to 1 million lb

Table 20. Producers of Copper(II) Oxide and Production Ranges (U.S. EPA, 1980) (Cont'd)

Producer and Location	Type of Production	1977 Production Range
Shell Chemical Co.		
Martinez, CA	Manufacturer	confidential
Tower Chemical Co.		
Clevmont, FL	Manufacturer/ Importer	confidential
SCM Corp.		
Hammond, IN	Manufacturer	zero
Johnstown, PA	Manufacturer	confidential
J&T& Baker Chemical Co.		
Phillipsburg, NJ	Manufacturer	10 to 100 thousand lb
The Prince Mfg. Co.		
Quincy, IL	Manufacturer	confidential
Bowmanstown, PA	Importer	
Mason Color and Chem. Wks.		
E. Liverpool, OH	Manufacturer	under 1000 lb
Macdermid Inc.		
Waterbury, CT	Manufacturer Produced Site Limited	confidential
The Harshaw Chem. Co.		
Cleveland, OH	Manufacturer	zero
Elyria, OH	Manufacturer	0.1 to 1 million lb
W&R& Grace and Co.		
Curtis Bay, MD	Manufacturer	under 1000 lb
Rohm and Haas Co.		
Philadelphia, PA	Manufacturer Produced Site Limited	confidential
The Babcock and Wilcox Co.		
Lynchburg, VA	Manufacturer	0.1 to 1 million lb
Wilson Products		
Reading, PA	Manufacturer	confidential
CP Chemicals Inc.		
Sewaren, NJ	Manufacturer	confidential
Powder Springs, GA	Manufacturer	

Table 20. Producers of Copper(II) Oxide and Production Ranges (U.S. EPA, 1980) (Cont'd)

Producer and Location	Type of Production	1977 Production Range
Unnamed Producers	---	0.1 to 1 million lb under 1000 lb 0.1 to 1 million lb 10 to 100 thousand lb
United Mineral and Chemical Corp. New York City, NY	Importer	under 1000 lb
Commercial Chemical Co. Memphis, TN	Importer	0.1 to 1 million lb
Philipp Bros. Chemicals New York City, NY	Importer	confidential
Celanese Corp. New York City, NY	Importer	0.1 to 1 million lb
Calabrian International New York City, NY	Importer	zero

8. Use

Copper(II) oxide is used as an oxidation and reduction catalyst in many organic reactions and in the sweetening of petroleum gases; as a pigment in making blue to green glasses, ceramics, porcelain glazes, and artificial gems; in galvanic electrodes; in correcting copper deficiencies in soil; as an optical-glass polishing agent; as an additive to impart flex and abrasion resistance to glass fibers; in antifouling paint; and as a flux in copper metallurgy (Winter _et_ _al_., 1965).

Cupric oxide is also used as a heat-collecting surface in solar energy devices (because thin, black coatings of CuO are nearly opaque to short wave length light, but nearly transparent to infrared radiation), as an ice nucleating agent in cloudseeding, and for the oxidation of exhaust gases for internal combustion engines (Kust, 1979).

A breakdown of the percentages of the total amount of copper(II) oxide produced that are used in various applications is not available.

9. Manufacturers and Distributors

The following are listed as manufacturers and distributors by SRI International (1980):

American Chemet Corp.	East Helena, MT
Belmont Metals Inc.	Brooklyn, NY
C.P. Chems., Inc.	Sewaren, NJ
Griffin Corp.	
Georgia Gulf Sulphur Div.	Bainbridge, GA
Kocide Chem. Co.	Houston, TX
Phelps Dodge Corp.	
Phelps Dodge Refining Corp., subsid.	Maspeth, NY
Philipp Brothers Chems., Inc.	
The Prince Mfg. Co., subsid.	Bowmanstown, PA Quincy, IL
Richardson-Merrell, Inc.	
J.T. Baker Chem. Co., subsid.	Phillipsburg, NJ
SCM Corp.	
Chemical/Metallurgical Div.	
Glidden Metals Group	Johnstown, PA

Southern California Chem. Co., Inc.	Bayonne, NJ Garland, TX Santa Fe Springs, CA Union, IL
United Catalysts Inc.	Louisville, KY

Data available from the U.S. EPA (1980) regarding producers of copper(II) oxide and production volumes are listed in Table 20.

The many distributors of cupric oxide include (1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Aldrich Chem.
Alfa Prod.
Anachemia Chem.
Apache Chem.
Atomergic Chemetals
Bodman Chem.
Calabrian International
Canadian Metafina
Cerac Inc.
Degussa Corp.
Delamar
Fehr Bros.
Filo Chem.
Fisher Sci.
Gallard-Schelsinger
Hall Chem.
Hummel Chem.
LaPine Sci.
MCB Reagents
Madison Industries
Mallinckrodt
Pacific Gateway
Pesses Co. The
Pfaltz and Bauer
Revelli Chem.
Ruger Chem.
Service Chem.
Shance Chem.
Spex Indus.
Sylvan Chem.
Tridom Chem.
United Mineral and Chem.

10. Manufacturing Processes

Cupric oxide is produced when copper is oxidized at a temperature above 300°C; it is manufactured either by furnace oxidation or by indirect oxidation of copper in the ammonia leaching process for the recovery of copper from ores (Winter et al., 1965). The latter process involves the indirect oxidation of copper by means of atmospheric oxygen. A cupric ammonium carbonate solution is the active agent here for the metallic copper, forming cuprous ammonium carbonate in a solution, which is then treated by blowing with air, restoring the copper to the cupric state. Part of the solution is then recycled and the remainder is boiled to drive off ammonia and carbon dioxide; a hydrated cupric oxide is precipitated, and generally decomposes to the oxide on drying (Winter *et al*., 1965; Utter and Tuwiner, 1949).

Furnace technology is used to produce both cupric and cuprous oxides (Winter *et al*., 1965; Utter and Tuwiner, 1949). In this operation, scrap copper (such as turnings, wire, slag, or scales obtained as by-products from other copper metallurgical operations) is heated to 800°C in a furnace in the presence of air or oxygen. Prolonged heating periods primarily produce the cupric salt. The furnace contents are cooled and pulverized to obtain a commercially usable cupric oxide.

Copper(II) oxide can also be produced by heating copper hydroxide or by the ignition of copper (II) nitrate or the basic carbonate (Kust, 1979).

11. Impurities or Additives

Like copper(I) oxide, copper(II) oxide is produced commercially in a wide variety of grades. A lower-purity grade, having the following typical analysis, is marketed (C.P. Chemicals, undated):

Total copper	75%
Cupric oxide	55.0%
Cuprous oxide	29.4%
Iron oxide	3.6%
Metallic copper	5.0%
Limestone	6.6%
Trace compounds	0.4%

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 151,685 workers are potentially exposed to copper(II) oxide.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper(II) oxide were not found in the literature searched.

14. Biological Effects

A. Animal Studies

(1) Acute Exposures

Batsura (1969) exposed rats to a condensation aerosol of copper oxide (50-80 mg/m^3) for 15, 30, 45, 60 or 180 minutes. Animals exposed for 1 hour or less were sacrified immediately and those exposed for 3 hours were sacrificed at 0, 3, 6, 12, 18, and 24 hours after termination of the experiment. Ultimately, as revealed by electron-microscopic examination, the particles had penetrated through all sections of the air-blood barrier and into the alveolar epithelial cells in animals exposed for three hours. Copper oxide crystals were found in the plasma six-hours after the three-hour exposure had begun. Aerosol dust was also found in the ultrastructures of the proximal nonvoluted tubules.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

(4) Carcinogenicity

Copper(II) oxide, administered as a single intramuscular injection (20 mg injected into the left, and 6 mg injected into the right thigh muscle), failed to induce tumors in 32 Wistar rats (Gilman, 1962). No carcinogenic activity occurred throughout the 20 month observation period.

(5) Mutagenicity

No information was found in the literature searched.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effcts

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

B. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

Metal fume fever is most likely caused by exposure to freshly produced copper oxide from fine copper dusts or fumes (McCord, 1960). The illness lasts 24 to 48 hours and is characterized by fever, chills, aching muscles, headache, and a dry mouth and throat.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

Studies of Chilean copper miners have demonstrated normal concentrations of copper in the liver and serum, despite years of exposure to insoluble copper and oxide dusts (Scheinberg and Sternlieb, 1969).

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) oxide were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) oxide as an occupational hazard was found in the literature searched.

P. COPPER(II) SULFATE

1. **Chemical Name**: Copper(II) Sulfate

2. **Chemical Structure**: $CuSO_4 \cdot 5H_2O$ (pentahydrate)

   $CuSO_4$ (anhydrous)

3. **Synonyms**:

Pentahydrate	Anhydrous
Blue copper AS	Copper monosulfate
Bluestone	Cupric sulfate, anhydrous
Blue vitriol	Roman vitriol
CSP	Sulfuric acid, copper (II) salt
Cupric sulfate, pentahydrate	
Roman vitriol	
Slazburg vitriol	
Sulfuric acid, copper(II) salt	

4. **Chemical Abstracts Service (CAS) Number**: 7758-98-7 (anhydrous)
   7758-99-8 (pentahydrate)

5. **Registry of Toxic Effects of Chemical Substances (RTECS) Number**:

   GL8800000 (anhydrous)
   GL8900000 (pentahydrate)

6. **Chemical and Physical Properties**:

Description:	grayish-white to greenish crystals (anhydrous) blue crystals or powder (pentahydrate)
Molecular Weight:	159.61 (anhydrous) 249.68 (pentahydrate)
Boiling Point:	---
Melting Point:	decomposes
Vapor Pressure:	---
Solubility:	Pentahydrate: 31.6 g/100 cc water (0°C) 203. g/100 cc water (100°C) soluble in methanol, glycerol; slightly soluble in ethanol Anhydrous: 14.3 g/100 cc water (0°C) 75.4 g/100 cc water (100°C) 1.04 g/100 cc methanol (18°C)

Specific Gravity: 3.6 (anhydrous)
2.284 (pentahydrate)
Stability: ---

7. Production

Of the common copper sulfates, cupric sulfate pentahydrate is the usual commercial form; relatively small amounts of the monohydrate and anhydrous forms are also marketed.

Copper sulfate is the compound, among the copper sulfates, that is produced in the largest quantities; production ranges for recent years are listed below (Kust, 1979; MCA, 1971, 1975; Lawler, 1977):

Year	Production (in millions of lb)
1976	64.0
1975	71.1
1974	84.0
1973	86.7
1971	69.1
1969	94.3
1968	83.7

Data available from the U.S. EPA (1980) regarding producers of copper sulfate and production volumes are listed in Table 21.

8. Use

The following tabulation presents the percentage of the total amount of copper sulfate produced that is used in each of the applications listed (Lowenheim and Moran, 1975):

	Percentage of Total
Fungicides	35
Algaecides	27
Feed supplement	4
Soil nutrient	2
Intermediates	11
Flotation	10
Electroplating	5
Petroleum and miscellaneous	1
Export	5
	100

Table 21. Producers of Copper Sulfate and Production Ranges
(U.S. EPA, 1980)

Producer and Location	Type of Producer	1977 Production Range
Chemical and Pigment Co.		
Pittsburg, CA	Manufacturer	confidential
Eagle-Picher Industries		
Galena, KS	Manufacturer	0.3 to 3 million lb
Galena, IL	Produced Site Limited	0.1 to 1 million lb
Fidelity Chemical Products Corp.		
Newark, NJ	Manufacturer	10 to 100 thousand lb
Phelps Dodge Refining Corp.		
New York City, NY	Manufacturer	10 to 50 million lb.
American Chemet Corp.		
East Helena, MT	Manufacturer	confidential
Engelhard Industries Div.		
Newark, NJ	Manufacturer	1 to 10 thousand lb
Frit Industries		
Ozark, AL	Manufacturer	12 to 120 thousand lb
Haven Chemical		
Philadelphia, PA	Manufacturer	under 1000 lb
Cities Services Co.		
Copperhill, TN	Manufacturer	confidential
Van Waters and Rogers		
Pinehurst, ID		1 to 10 million lb
Kent, WA	Manufacturer	1 to 10 million lb
Valumet Processing Corp.		
Sayreville, NJ	Manufacturer	0.1 to 1 million lb
ARS Chemical Corp.		
Providence, RI	Manufacturer	10 to 100 thousand lb
Duval Corp.		
Battle Mountain, NV		50 to 100 million lb
Sahuarita, AZ	Manufacturer	10 to 50 mllion lb
Kingman, AZ	Produced Site Limited	50 to 100 million lb
Macdermid Inc.		
Waterbury, CT	Manufacturer	confidential

Table 21. Producers of Copper Sulfate and Production Ranges (U.S. EPA, 1980) (Cont'd)

Producer and Location	Type of Producer	1977 Production Range
St. Louis Plant St. Louis, MO	Manufacturer	confidential
Harstan Chemical Corp. Brooklyn, NY	Manufacturer	0.1 to 1 million lb
CP Chemicals, Inc. Sewayen, NJ	Manufacturer	confidential
Asarco Inc. Corpus Christi, TX	Manufacturer Produced Site Limited	2 to 20 million lb
Unnamed	Manufacturer	0.21 to 2.1 million lb
United Mineral and Chemical Corp. New York City, NY	Importer	under 1000 lb
Nissho-Iwai American Corp. New York City, NY	Importer	10 to 50 million lb
Cominco American, Inc. Spokane, WA	Importer	10 to 100 thousand lb
EM Laboratories Elmsford, NY	Importer	1 to 10 thousand lb
Graymor Chemical Co. Pine Brook, NJ	Importer	30 to 300 thousand lb
J.B. Chemical Co. N. Hollywood, CA	Importer	0.1 to 1 million lb.
H.J. Baker and Bro. Inc. New York City, NY	Importer	1 to 10 million lb
American Hoescht Corp. Bridgewater, NJ	Importer	confidential
Deka Minerals, Inc. New York City, NY	Importer	0.1 to 1 million lb
The Frank Herzl Corp. New York City, NY	Importer	under 1000 lb
Calabrian International New York City, NY	Importer	1 to 10 million lb

Similar information, according to Lawler (1977), follows:

	Percentage of Total
Agricultural (e.g., fungicides, insecticides, algacides, seed treatment and soil amendment, and as a nutrient for animal and poultry feeds)	50
Industrial (e.g., petroleum refining; dyes; flotation agent in treatment of cobalt, lead, and zinc ores; preservative for wood and animal hides; intermediate in production of other copper compounds)	46
Exports	4

9. Manufacturers and Distributors

The manufacturers of copper sulfate, listed by SRI International (1980), are as follows:

Atlantic Richfield Co.	
The Anaconda Co., subsid.	
Anaconda Copper Co., Div.	Great Falls, MT
Cities Service Co.	
Minerals Group	Copperhill, TN
C.P. Chems., Inc.	Sewaren, NJ
Eagle-Picher Indust., Inc.	
Agricultural Chems. Div.	Cedartown, GA
	Fairbury, NB
	Galena, KS
Frit Indust., Inc.	Walnut Ridge,
AR Harstan Chem. Corp.	Brooklyn, NY
Imperial West Chem. Co.	Antioch, CA
Kocide Chem. Co.	Houston, TX
Liquid Chem. Corp.	Hanford, CA
Madison Indust., Inc.	Old Bridge, NJ
Phelps Dodge Corp.	
Phelps Dodge Refining Corp., subsid.	El Paso, TX
	Maspeth, NY
	St. Ann, MO
Philipp Brothers Chems., Inc.	
The Prince Mfg. Co., subsid.	Bowmanstown, PA
	Quincy, IL
Richardson-Merrell, Inc.	
J.T. Baker Chem. Co., subsid.	Phillipsburg, NJ
subsid.	Bayonne, NJ
Southern California Garland, TX	
Chem. Co., Inc.	Santa Fe Springs, CA
	Union, IL
Univar Corp.	
Van Waters and Rogers, div.	Kent, WA
	Pinehurst, ID

Data available from U.S. EPA (1980) regarding producers of copper sulfate and production ranges are listed in Table 21.

In addition to being distributed by the manufacturers, copper sulfate is distributed by the following (Chemical Week: 1981 Buyers' Guide Issue, 1980; 1980-81 OPD Chemical Buyers Directory, 1980; Chemical Sources--USA, 1980):

Aldrich Chem.
Alexander M. McIver and Son
Alfa Prod.
Amer. Sci.
American Hoechst Corp.
Anachemia Chem.
Apache Chem.
Asher-Moore Co.
Ashland Chemical Co.
Atomergic Chem.
Auric Corp.
Badman Chem.
Baker, H.J. and Bros., Inc.
Browning Chemical Corp.
Calabrian International Corp.
Canadian Metafina
Captree Chemical Co.
Chem. Metals Ind.
Chem. Services
Chemical Ind.
Chemical Specialities
Chemical and Pigment Co.
Conray Chem.
D. and O. Chemical
Davos Chemical Corp.
Delamar Filo
E.M. Sargeant Pulp
  and Chemical Co., Inc.
EM Laboratories, Inc.
Eagle Chemical Co.
Faesy and Besthoff, Inc.
Fehr Bros.
Fidelity Prod.
Fisher Scientific Co.
Gallard-Schelsinger
Gibco Lab.
Graymor Chemical Co., Inc.
Griffin Corp.
Gulf Chemical and
  Metallurgical Co.
Hach Chem.
International Commodities
  Export Corp.
Ishihara Corp. (U.S.A.)
Jones Chem.
Jones Chemical Inc.
LaPine Sci.
M and T Chem.
Mallinckrodt Inc.
MCB Reagents
McKesson Chemical Co.
Medical Chem.
Monomer-Polymer and Dajac
Monterey Chem.
Mutchler Chemical Co., Inc.
Namolco Minerals, Inc.
Orion Chem.
Pacific Gateway
Pfaltz and Bauer
Pioneer Salt and Chem.
Powell, Inc.
Reliable Chem.
Revelli Chem.
Riches-Nelson, Inc.
Robeco Chemicals, Inc.
RP Chemical Enterprises, Inc.
Sal Chem.
Shance Chemical Corp.
Sigma Chem.
Signo Trading
Simmler Inc.
G.F. Smith Chem. Co.
Spex Indus.
Sylvan Chemical Corp.
T.R. Americas
Thatcher Chem.
Thompson-Hayward Chemical Co.
Transene Co.
Tridom Chem.
Turner Joseph and Co.
United Mineral and
  Chemical Co.

Harshaw Chemical Co.
Helm NY
J.F. Henry Chemical Co., Inc.
Holtrachem, Inc.
ICD Group Inc.
Valley Zinc Corp.
Westco Chemicals, Inc.
Wilson and Geo. Meyer and Co.
Worth Chem.

10. Manufacturing Processes

Copper sulfate is commonly manufactured according to the following equation:

$$2Cu + 2H_2SO_4 + O_2 \text{ (air)} + 8H_2O \longrightarrow 2CuSO_4 \cdot 5H_2O$$

Copper sulfate is made by the reaction of scrap or shot copper with sulfuric acid and oxygen (air). The copper is fed to an oxidizing tower, and a sulfuric acid-water mixture (20% sulfuric acid) is circulated through the bed while air is blown through the bottom of the tower. Copper sulfate pentahydrate is recovered from the resulting solution by crystallization; the liquor is recycled to the tower along with makeup sulfuric acid. The process is shown in Figure 11.

Much of the copper sulfate on the market is a by-product in copper refining. Copper is often leached from its ores with sulfuric acid; the resulting solution is treated in an electrolytic cell using an insoluble anode. Copper is plated at the cathode, regenerating sulfuric acid. The spent electrolyte may then be used on a fresh batch of ore. After reuse, the cell solution may be pumped to lead-lined tanks for evaporation and crystallization of copper sulfate pentahydrate (Lowenheim and Moran, 1975).

11. Impurities or Additives

Copper sulfate is available commercially in a technical, C.P., and N.F. grade; the required purity comforms to standards established through usage. Impurities depend upon the method of manufacture and may contain traces of nickel, iron, arsenic, antimony, lead, and fluorine.

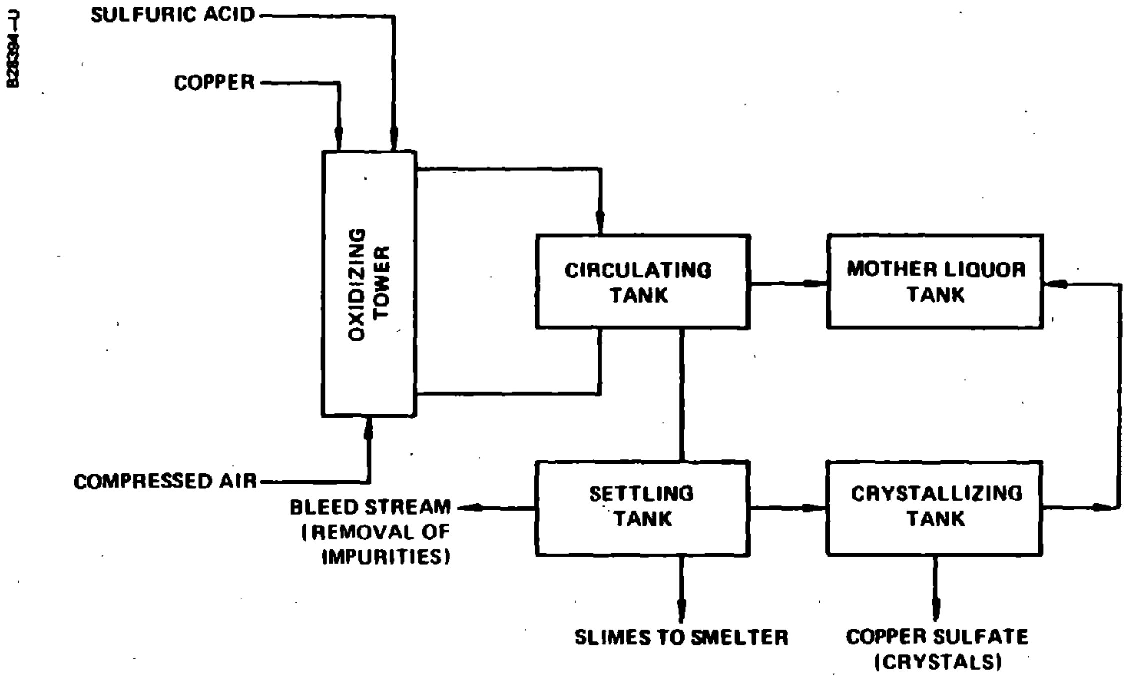


Figure 11. Copper(II) Sulfate Manufacture (Lowenheim and Moran, 1975)

12. Occupational Exposure

The National Occupational Hazard Survey indicates that 233,474 workers are potentially exposed to copper(II) sulfate.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper sulfate were not found in the literature searched.

14. Biological Effects

A. Animal Studies

(1) Acute Exposures

An acute oral LD_{50} of 960 mg/kg copper sulfate in male Wistar rats was reported by Smyth and coworkers (1969). The National Research Council (NRC, 1977) reported that, when administered to sheep, copper sulfate is 2 to 4 times less toxic than copper chloride is.

Information on the general toxicologic effects resulting from acute exposure is scarce, particularly for non-ruminant mammals. Early investigations by Moore and coworkers (1913) with copper sulfate, conducted on guinea pigs (22), rats (15), and mice (11), revealed similar changes in the three species. In a typical example used by the authors to represent the general effect, a 320 g guinea pig was given copper sulfate (0.2 grams) subcutaneously. Diarrhea, partial motor paralysis and coma occurred before respiration ceased at 35 hours post injection. An immediate autopsy revealed ulceration and a general inflammatory condition of the mucosa and submucosa of the ileum. The stomach, lung, liver, and kidney appeared normal but the presence of copper was demonstrated in renal tissue.

In sheep, the signs of acute copper toxicity are abdominal pain, excessive salivation, vomiting, and greenish fluid diarrhea. Collapse and death occur within 24-48 hours of administration of a fatal dose

(NRC, 1977). Ishmael and Gopinath (1972) studied the pathology of acute copper toxicity in 10 month-old sheep by intravenously injecting 25 mg of copper (3 sheep), 50 mg copper (4 sheep), or 100 mg copper (2 sheep) as copper sulfate. Liver biopsies performed 48 hours after injection revealed centrilobular necrosis that was associated with a leakage of liver-specific enzymes into the blood of sheep receiving 25 or 50 mg copper. These changes were resolved 1 week later. Two animals at the 50 mg dose level that died during the experiment had severe kidney damage. Both animals that received 100 mg copper showed intense congestion of the abomasum and duodenum at necropsy (6 hours after injection). One of the sheep given 100 mg copper died within 2 hours of injection.

Ahmed et al. (1979) investigated the effects of injected (intravenous) copper sulfate in 9 conscious sheep on the following hemodynamic parameters: pulmonary arterial pressure (Ppa), pulmonary arterial wedge pressure (Ppaw), cardiac output (Qp), systemic arterial pressure (Psa), pulmonary vascular resistance (PVR) and heart rate (HR). After a total dose of 300 mg copper sulfate/animal mean Ppa, mean Ppaw, PVR, and mean Psa increased to 218%, 217%, 320%, and 107% of baseline, respectively. HR and Qp decreased to 78% and 70%, respecitvely. After two hours all parameters returned to baseline except mean Ppa (148%), PVR (237%) and Qp (73%). Three animals died of ventricular fibrillation. Ahmed et al. stated that administration of primary copper sulfate in sheep might represent a model of human pulmonary hypertension. An increase of Ppa had also been demonstrated in preliminary studies with anesthetized dogs.

(2) Subchronic Exposures

Diets high in copper sulfate (up to 250 ppm) given to swine for 8 weeks post-weaning resulted in daily weight gain increases over controls. Overall, no effect on rate of weight gain was observed with continued feeding beyond 8 weeks at this copper level. The amount of copper that accumulated in the liver increased proportionately with increasing dietary copper; when copper sulfate was removed from the diet, however, hepatic copper levels also dropped (NRC-42, 1974; Kline et al., 1971).

In an experiment reported by Gopinath and coworkers (1974), sheep underwent hemolytic crisis after nine weeks of daily drinking doses with 20 mg of copper sulfate per kilogram of body weight. Before the hemolytic crisis, whole blood copper levels did not differ from those of controls, but, at the time of the crisis, blood copper levels underwent a marked elevation. The livers of both prehemolytic and hemolytic sheep showed copper concentrations of approximately 500 ppm, in contrast to concentrations in controls, which averaged 50 ppm. Severe tubular injury occurred in the kidneys of the hemolytic sheep. Ahmed et al. (1979) administered 50 mg of copper sulfate either daily or on alternate days to 5 sheep for one to three months. There was a sustained increase in mean pulmonary arterial pressure (233% of baseline), and a marked increase in pulmonary vascular resistance (417% of baseline). No significant changes were observed in mean systemic arterial pressure or pulmonary arterial wedge pressure. Histopathologic examination of the pulmonary blood vessels of one animal revealed no abnormalities.

Systemic effects from parenteral and dietary administration of copper compounds have been reported in rats (Piscator, 1977). When copper sulfate was administered daily by subcutaneous injection for 60 days (0.26 mg copper/dose), it was found that great amounts of copper (about 1000 ppm) were stored in the liver. Controls stored only 4.7 ppm. In addition, the treated rats developed decreases in hematocrit, hemoglobin, and erythrocytes. On the average, these animals survived the treatment for 67 days. Lesions of both the kidneys and liver were noted. In other studies, male Sprague-Dawley rats were injected (intraperitoneal) daily with 1.25, 2.5, or 3.75 mg Cu/kg body weight in the form of copper sulfate (Lal and Sourkes, 1971). Animals were killed and examined at 6, 12, and 18 week intervals. While the smallest dose had no significant effect, the larger doses caused a marked depression in body weight in rats treated for 18 weeks. With the two higher doses, a decrease in liver weight paralleled body weight changes at six weeks but not at 18 weeks. At 12 and 18 weeks, all rats had developed a condition of megacolon, possibly attributed to the destruction of the myenteric plexus.

Pimentel and Marques (1969) exposed guinea pigs for 6 months to an atmosphere saturated with Bordeaux mixture (1 to 2% copper sulfate neutralized with hydrated lime), which is used in spraying vineyards. Four of the 6 animals tested developed local micronodular lesions of the lungs, but x-ray examination of 2 animals sacrificed 3 months later indicated some reversal of the lesions.

(3) Chronic Exposures

In an abstract of a Bulgarian study copper sulfate (at 5% of the LD_{50}) caused coronary damage and cardiosclerosis in male white rats (Zlateva, 1978). The exact dose, duration, and route of administration were not specified. Reportedly, the degree of myocardiosclerosis was dose dependent.

(4) Carcinogenicity

No information was found in the literature searched.

(5) Mutagenicity

Copper sulfate was inactive in the Ames assay with *Salmonella typhimurium* LT-2 (Lemma and Ames, 1975).

Kimura and Makino (1963) showed that copper sulfate (administered intraperitoneally at 300 mg/kg body weight) had a slight inhibitory effect on the MTK-Sarcoma III, a rat ascites tumor. The tumor cells manifested the following cellular events: 1) lobated nuclei, 2) karyorrhexis and, 3) multipolar spindle formation. Recovery of tumor cells after injection was between 24-48 hours.

Castro et al. (1979) tested metal salts for their ability to enhance transformation of Syrian hamster embryo cells (HEC) by a simian adenovirus, SA7. Copper sulfate exhibited an increase in viral transformation rate when cells were treated for 18 hours with a concentration of 0.08 mM.

Demerec et al. (1951), using E. coli (strains B/Sd-4/1,3,4,5 and B/Sd-4/3,4), found that copper sulfate was mutagenic (0.075 mg/l) in the lower range of survival.

Copper sulfate increased the lethal mutation rate of the X-chromosome in Drosophila melanogaster by parenteral injection of a 0.1% solution into mature larvae and by immersion of naked, fertilized eggs with a concentrated aqueous solution for ten minutes (Law, 1938).

(6) Teratogenicity

There are limited data indicating teratogenic and embryotoxic effects of copper sulfate compounds. Pregnant hamsters were intravenously injected with various doses of either copper sulfate (2.13 to 10.0 mg Cu/kg) or copper citrate (0.25 to 4.0 mg Cu/kg) on the 8th day of gestation (Ferm and Hanlon, 1974). Workers examined embryos and gestation sacs upon sacrifice of the animals 4 to 5 days later. Their results showed an increase in embryonic resorptions and in development defects of surviving offspring (Table 22). Malformations of the heart (ectopia cordis) appeared to be a specific effect of copper toxicity. Although both forms of copper ion were teratogenic, copper citrate was found to be slightly more embryocidal and considerably more embryopathic than was copper sulfate. Additional studies showed that on day 8 of

Table 22. Effect of Copper Salts on Hamster Embyronic Development (Ferm and Hanlon, 1974)

Dose Level (mg Cu/kg)	No. of mothers treated	No. of gestation sacs	No. of living embryos[a]	No. of resorptions[a]	No. of abnormal embryos[a]
<u>Copper sulfate</u>					
2.13	16	210	155 (74)	55 (26)	12[b] (6)
4.25	3	49	7 (14)	42 (86)	4[c] (8)
7.50	3	30	0 (0)	22 (74)	---
10.0	2	Maternicidal			
<u>Copper citrate</u>					
0.25-1.50	13	172	143 (83)	29 (16)	4[d] (2)
1.80	6	81	48 (59)	33 (41)	14[e] (17)
2.20	8	99	65 (66)	34 (34)	35[f] (35)
4.0	2	Maternicidal			
<u>Controls</u> (demineralized water)					
0.5-1.0 ml/100 g	10	125	115 (92)	10 (8)	0 (0)

[a] Numbers in parentheses represent percentages of total number of gestation sacs.

[b] Five thoracic wall hernias, 4 encephalocoeles, 2 spina bifida, 1 microphthalmia.

[c] One exencephaly, 1 hydrocephalus, 1 abdominal hernia, 1 abnormal spinal curvature.

[d] Two tail abnormalities, 1 microphthalmia, 1 craniorrhachischisis.

[e] Thirteen tail defects, 1 meningocoele.

[f] Twenty-five tail defects, 6 thoracic wall defects, 2 microphthalmia, 1 abdominal wall defect, 1 facial cleft.

gestation the hamsters' placentas were permeable to ^{64}Cu citrate, suggesting a direct teratogenic effect of copper upon the developing embryos.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

Lal and Sourkes (1971) studied the effect of duration and dose (see Section 14.A.2. for experimental detail) of copper sulfate administration on the intracellular distribution of copper in rat liver. The four subcellular fractions measured were nuclear, mitochondrial, supernatant and microsomal.

Coulter _et_ _al_. (1978) immersed lenses from the eyes of 60 day-old rats in nutrient solutions containing concentrations of 0, 10, 20, 50 or 100 µM copper sulfate. Four lenses at each concentration level were cultured for 24 hours at 35°C. Lenses exposed to 0 or 10 µM copper remained clear, and those incubated with 20, 50, or 100 µM copper grew cloudy, primarily in the equatorial region of the lens. The cloudiness indicated an inhibitory effect of copper on glucose utilization and sodium-potassium transport. Lens cloudiness was observed to increase with increasing copper concentrations.

B. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

Copper sulfate is a strong emetic used in treatment of poisoning. In children, the recommended dose is 250 mg copper sulfate (100 mg copper). In adults, vomiting is induced by 1 g of copper sulfate (400 mg copper) (Piscator, 1977). Although vomiting and diarrhea generally protect the patient, copper sulfate's use as an emetic has been reduced because of its systemic effects: hepatic necrosis, hemolysis, gastrointestinal bleeding, hematuria, hemoglobinuria, oliguria, azotemia, proteinuria, hypotension, tachycardia, convulsions, coma, and death (Sanghvi _et_ _al_., 1957; Chuttani _et_ _al_., 1965; Stein _et_ _al_., 1976).

Copper sulfate, taken orally in large amounts (1 g or more) with suicidal intent, has caused icterus and damage to the kidneys (Chuttani _et_ _al_., 1965). In those cases, blood copper levels were measured at 8 mg/l; at blood copper levels of 3 mg/l, gastrointestinal distress was the only effect observed. The 48 patients in this study had ingested 1 to 100 g of copper sulfate; among this group, 9 persons died (Chuttani _et_ _al_., 1965).

Sanghvi _et_ _al_. (1957) also reported two cases in young men who developed hypotension, sulfhemoglobinemia, and acute renal failure after ingesting "large amounts" (unspecified) of copper sulfate. Blood urea levels rose to 120 and 200 mg percent before death, five and eight days after admission, respectively. In both cases, acute renal failure occurred 24 hours after the development of sulfhemoglobinemia. Five hours after ingesting more than 50 g of copper sulfate, a 27 year old man developed deep cyanosis followed by severe oligurice. Circulatory collapse, hypotension, shock and coma occurred during the tenth hour and death occurred 16 hours after ingestion (Chugh _et_ _al_., 1975). In the absence of cardiac or pulmonary disease, deep cyanosis suggested methemoglobinemia, which was confirmed. After accidential ingestion of 3 g of copper sulfate, an 18 month old boy developed hemolytic anemia and renal tubular damage but survived this episode with chelator drug therapy (Walsh _et_ _al_., 1977).

Another therapeutic application of copper sulfate, treatment of severe skin burns, caused a child to suffer severe anemia with eventual hemolytic crisis and jaundice after several applications. Absorption of copper from the dressings was judged to be responsible when tests showed levels of copper in the urine and serum to be 2.2 mg/l and 5.4 mg/l, respectively. A slight degree of liver injury was also noted. Treatment, including chelation by penicillamine administered by mouth, brought quick recovery (Holtzman et al., 1966).

Accidential ingestion of copper sulfate by 18 workers led to gastroenteritis (Semple et al., 1960). The copper sulfate was ingested from tea that was prepared from water stored and boiled in a copper-lined container. A deposit of copper sulfate was encrusted inside the boiler.

Vineyard sprayers lung, a disease attributed to inhalation of Bordeaux mixture (a 1 to 2.5% solution of copper sulfate neutralized with hydrated lime (which is sprayed on grapevines to prevent mildew), is characterized by the following symptoms: weakness, loss of appetite and weight and progressive dyspnea sometimes accompanied by coughing.

(3) Target Organ Toxicity

In humans, ingestion of excessive amounts of copper sulfate has resulted in corrosion of gastric and intestinal epithelium (Walsh et al., 1977), acute hemorrhagic necrosis of the small intestine and acute tubular necrosis of the kidneys (Stein et al., 1976). Histopathologic examination of the kidney revealed the severest changes in the ascending loop of Henle, the distal convoluted tubules, and the collecting tubules (Sanghvi et al., 1957). They were focal in nature and consisted of degeneration and necrosis of the epithelium. The proximal tubule showed cloudy swelling and degeneration of the epithelium, but no evidence of necrosis. Glomeruli were essentially normal in appearance.

Histopathologic examination of hepatic tissue revealed dilation of central veins, cell necrosis, bile thrombi (Chuttani et al., 1965), and opaque, yellow mottling (Stein et al., 1976). Stein and coworkers also reported an excessive increase in liver weight. Pimentel and Menezes (1975) examined livers of three patients with vineyard sprayers lung and in each case, sarcoid-type or histiocytic granulomas were found near the portal tracts. The histiocytic granulomas appeared as well-defined oval or rounded nodules similar to those found in the lungs of vineyard sprayer's patients. Copper was detected histochemically in both types of lesions.

Histopathologic examination of vineyard sprayers lung tissue revealed lymphocytic cellular infiltration of the septa and copper-containing macrophages present in the alveoli. Macroscopically, the lungs showed greenish-blue patches and formation of irregular cavities. X-rays revealed micronodular dissemination or a reticuleonodular shadowing in the lower portion of the lungs (Pimentel and Marques, 1969; Villar, 1974).

(4) Epidemiology

In Portugal, Pimentel and Marques (1969) and Villar (1974) have described 17 cases of vineyard sprayer's lung, a disease attributed to the inhalation of Bordeaux mixture (a 1 to 2.5% solution of copper sulfate neutralized with hydrated lime). This mixture, widely used in France, Portugal and Italy, is sprayed on grapevines to prevent the development of mildew; typically, the vines are sprayed intermittently (2 to 12 times) during three months (April-June) each year. For the 15 patients observed by Villar (1974), the time since the last exposure ranged from 1 to 43 years; and 7 patients were smokers. One individual had been exposed to Bordeaux mixture for 4 years and 3 others for more than 20 years, but the duration of exposure was not indicated for the other persons.

The disease typically progressed in one of three ways (Villar, 1974): Some patients improved considerably once exposure to Bordeaux mixture ceased. In other cases, the patients' conditions remained stable until a bronchopulmonary infection or possibly exposure to some other dust prompted further progression of the disease. In a third group, the most common chronic form of the disease--tumor-like, symmetric, massive opacities in the upper lobes--developed. Even in some of this last group, follow-up for 3 years showed further retraction and calcification of the lesions. Among the 15 cases of vineyard sprayer's disease described by Villar (1974), 3 cases of lung cancer were diagnosed. It should be noted that although elevated incidences of lung and liver cancer have been reported in vineyard workers from certain regions of France (Poirier _et_ _al_., 1973) and Germany (Denk _et_ _al_., 1969), exposure in these instances was to arsenic-containing insecticides; in Portugal, arsenic compounds have never been used in vineyard fungicides, and Villar suggests that the high incidence of lung cancer in these workers may be related to the copper found in their lesions.

15. Ongoing Studies

Several studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) sulfate were found.

17. Sources of Additional Relevant Information

One NIOSH Health Hazard Evaluation relating to copper sulfate has been conducted at Rocky Mountain Mfg. and Wire Co., Cleaning Dept., Pueblo, CO (HHE No.-HHE 76-108-365).

18. Other Pertinent Data

No other information that would aid in the assessment of copper as an occupational hazard was found in the literature searched.

Q. COPPER(II) SULFIDE

1. Chemical Name: Copper(II) Sulfide

2. Chemical Structure: CuS

3. Synonyms: Cupric sulfide
   Covellite

4. Chemical Abstracts Service (CAS) Number: 1317-40-4

5. Registry of Toxic Effects of Chemical Substances (RTECS) Number:

   Not listed

6. Chemical and Physical Properties:

Description:	black powder or lumps
Molecular Weight:	95.60
Boiling Point:	decomposes at 220°C
Melting Point:	103°C (transition point)
Vapor Pressure:	---
Solubility:	0.000033 g/100 cc water (18°C); soluble in HNO_3, KCN, hot HCl, H_2SO_4; insoluble in alcohol and alkalies
Specific Gravity:	4.6
Stability:	---

7. Production

Data available from the U.S. EPA (1980) regarding producers of copper sulfide and production volumes are presented in Table 23.

8. Use

Copper sulfide is useful in antifouling paints, in the development of aniline black dye in textile printing, and in the preparation of mixed catalysts (Winter et al., 1965).

9. Manufacturers and Distributors

SRI International (1980) lists the following manufacturer:

SCM Corp.
    Chemical/Metallurgical Div.
        Glidden Metals Group   Hammond, IN

Table 23. Producers of Copper(II) Sulfide and Production Ranges (U.S. EPA, 1980)

Producer and Location	Type of Production	1977 Production Range
McGean Chemical Co. Cleveland, OH	Manufacturer	10 to 100 thousand lb
Union Carbide Corp. Bishop, CA	Manufacturer	1 to 10 million lb
The St. Louis Plant St. Louis, MO	Manufacturer	zero
SCM Corp. Hammond, IN	Manufacturer	zero
Orion Research Inc. Cambridge, MA	Manufacturer	under 1000 lb
General Electric Co. Selkirk, NY	Manufacturer	confidential
Pennwalt Corp. Homer, NY	Manufacturer	under 1000 lb
Unnamed	---	1 to 10 thousand lb

Data available from the U.S. EPA (1980) regarding producers of copper sulfide and production volumes are listed in Table 23.

Distributors of copper sulfide include 1980-81 OPD Chemical Buyers Directory, 1980; Chemical Week: 1981 Buyers' Guide Issue, 1980; Chem Sources--USA, 1980):

Alfa Prod.
Anachemica Chem.
Apache Chem.
Atomergic Chemetals
Bodman Chem.
Cerac Inc.
Chem. Procurement Lab.
Chem. Services
Fehr Bros.
Fisher Sci.
Gallard-Schlesinger
Great Western Inorganics
ICN/K and K
MCB Reagents
NoahChem.
The Pesses Co.
Pfaltz and Bauer
Sattva Trading Co.
Tridom Chem.

10. Manufacturing Processes

Although copper sulfide occurs naturally, the compound of commerce is artificially manufactured. It can be prepared by treating a cupric salt with hydrogen sulfide or sodium sulfide. The resulting suspension can be coagulated with hydrochloric acid to form a pasty precipitate that is useful commercially. It can also be prepared by heating cuprous sulfide with flowers of sulfur or by digesting it with sulfuric acid and other methods (Winter et al., 1965).

11. Impurities or Additives

No information was found in the literature searched.

12. Occupational Exposure

The National Occupational Hazard Survey does not provide an estimate of the number of workers who are potentially exposed to copper(II) sulfide.

13. Control Technology and Work Practices

Specific factors that may contribute to or prevent employee exposure to copper sulfide were not found in the literature searched.

14. Biological Effects

A. Animal Studies

(1) Acute Exposures

No information was found in the literature searched.

(2) Subchronic Exposures

No information was found in the literature searched.

(3) Chronic Exposures

No information was found in the literature searched.

(4) Carcinogenicity

Copper(II) sulfide, administered as a single intramuscular injection in 30 Wistar rats (20 mg injected into both the left and right thigh muscles), was not carcinogenic (Gilman, 1962). The period of observation was approximately 20 months following exposure.

(5) Mutagenicity

In an investigation of the effect of copper(II) sulfide (150 mg/kg body weight administered by intraperitoneal injection) on the MTK-sarcomaIII rat ascites tumor *in vivo*, Kimura and Makino (1963) reported the development of mitotic abnormalities, as evidenced by chromatic aggregation, and stickiness, contraction, scattering, lagging, and clumping of chromosomes.

(6) Teratogenicity

No information was found in the literature searched.

(7) Reproductive Effects

No information was found in the literature searched.

(8) Other Relevant Information

No information was found in the literature searched.

B. Human Studies

(1) Pharmacokinetics

No information was found in the literature searched.

(2) Health Effects

No information was found in the literature searched.

(3) Target Organ Toxicity

No information was found in the literature searched.

(4) Epidemiology

Studies of Chilean copper miners have demonstrated normal concentrations of copper in the liver and serum, despite years of exposure to insoluble copper sulfide dusts (Scheinberg and Sternlieb, 1969).

15. Ongoing Studies

A number of studies on copper compounds are being conducted. See Appendix B for details.

16. Exposure Standards

No recommended or promulgated occupational exposure standards for copper(II) sulfide were found.

17. Sources of Additional Relevant Information

No sources of additional relevant information were identified.

18. Other Pertinent Data

No other information that would aid in the assessment of copper(II) sulfide as an occupational hazard was found in the literature searched.

APPENDIX A - COPPER COMPOUNDS

The following list includes all of the compounds considered under the copper compound class. The compounds in the list were identified primarily from the following sources: U.S. EPA TSCA list and U.S. EPA (1980) SRI International (1980), USITC (1980), Kirk-Othmers' Encyclopedia of Chemical Technology, The Merck Index (1976), and Chem Sources--USA (1980).

Chemical Abstract Service numbers are listed where available.

Compound	CAS No.
Copper abietate	10248-55-2
Copper(I) acetate	598-54-9
Copper(II) acetate	142-71-2
Copper(II) acetate, basic	52503-63-6
Copper(II) acetate monohydrate	6046-93-1
Copper acetate oxide	6533-47-7
Copper(II) acetoarsenite	12002-03-8 1299-88-3
Copper(II) acetylacetonate	13395-16-9
Copper(I) aetylide	1117-94-8
Copper(II) amine sulfate	14283-05-7
Copper amino acid chelate	--
Copper(I) ammonium acetate	43043-77-2
Copper(II) ammonium acetate	23087-46-9
Copper ammonium arsenate	32680-29-8
Copper ammonium carbonate	33113-08-5
Copper(I) ammonium chloride	--
Copper(II) ammonium chloride	--
Copper ammonium hydroxide	17500-49-1
Copper(II) ammonium sulfate	--
Copper(I) antimonide	12054-25-0
Copper(II) antimonide	12054-21-6
Copper(II) arsenate	10103-61-4 7778-41-8
Copper arsenate hydroxide	16102-91-4
Copper(I) arsenic sulfide	--
Copper(I) arsenide	12005-75-3
Copper(II) arsenide	12254-86-3
Copper(II) arsenite	10290-12-7 1302-97-2
Copper aspinnate	23642-01-5

Compound	CAS No.
Copper(II) benzoate	533-01-7
Copper(II) benzoyl acetonate	14128-84-8
Copper bicarbonate	7492-68-4
Copper bis(salicylaldehyde)	14523-25-2
Copper(II) borate	39290-85-2
Copper bromate	--
Copper(I) bromide	7787-70-4
Copper(II) bromide	7789-45-9
Copper(I) tert-butoxide	--
Copper butylphthalate	--
Copper butyrate	540-16-9
Copper iso-butyrate	--
Copper caprylate	--
Copper(II) carbonate	1184-64-1 16211-10-2
Copper(II) carbonate, basic	12069-69-1
Copper chelate	--
Copper(II) chlorate	14721-21-2
Copper(II) chlorate, tetrahydrate	10294-45-8
Copper(I) chloride	7758-89-6
Copper(II) chloride	7447-39-4 12258-96-7
Copper(II) chloride, basic	16004-08-3 1332-65-6 12167-76-9 12356-86-4
Copper(II) chromate(III)	12018-10-9
Copper(II) chromate(VI)	13548-42-0 12617-87-7 13675-47-3
Copper(II) chromate, basic	1308-09-4
Copper chromite	11104-65-7
Copper(II) chromite	12018-10-9
Copper chromite barium	--
Copper chromite zinc oxide	--
Copper(II) citrate	866-82-0
Copper(II) citrate, hydrate	6020-30-0
Copper cobalticyanide	--
Copper(II) columbate	--
Copper(I) cyanide	544-92-3
Copper(II) cyanide	4367-08-2
Copper(II) cyclohexylbutyrate	2218-80-6

Compound	CAS No.
Copper(II) dichromate	13675-47-3
Copper(II) dichromate, dihydrate	12018-10-9
Copper dihydrazinium sulfate	--
Copper diiron tetraoxide	--
Copper(II) dimethyldithiocarbamate	137-29-1
Copper disodium ethylenediamine tetracetate	14025-15-1
Copper(II) ethylacetoacetate	--
Copper(II) ethylacetyl acetonate	14284-35-3
Copper(II) ethylenediamine	14552-35-3
Copper ethylenediamine-N,N'-diacetic acid	32575-57-8
Copper ethylenediamine gold cyanide	18974-18-0
Copper ethylediamine nickel cyanide	63427-32-7
Copper ethylenediamine silver cyanide	67859-40-9
Copper ethylenediamine sulfate cyanide	--
Copper ethylenediamine tetracetate	54452-03-1
Copper ethylenediamine zinc cyanide	67859-43-2
Copper(II) 2-ethylhexanoate	149-11-1 22221-10-9
Copper ethyl xanthate	--
Copper(II) ferrate (III)	12018-79-0
Copper(II) ferricyanide	--
Copper ferrite	--
Copper(II) ferrocyanate	--
Copper(II) ferrocyanide	13601-13-3
Copper(II) ferrous sulfide	1308-56-1
Copper(I) fluoborate	14708-11-3
Copper(II) fluoborate	38465-60-0
Copper(II) fluoride	7789-19-7
Copper(II) fluorosilicate	12062-24-7
Copper(II) formate	544-19-4
Copper(II) formate tetrahydrate	5893-61-8
Copper gallium selenide	12018-83-6
Copper gallium sulfide	12158-59-7
Copper gallium telluride	12018-84-7
Copper(II) gluconate	527-09-3
Copper(II) gluconate monohydrate	6020-31-1
Copper glutanate	--
Copper(II) glycinate	13479-54-4
Copper glycolate	--
Copper guaiacolsulfonate	--

Compound	CAS No.
Copper heptanoate	5128-10-9
Copper(II) hexacyanoferrate(II)	13601-13-3
Copper hexafluoroacetylacetone	--
Copper(I) hydride	13517-00-5
Copper hydroselenite	10031-38-6
Copper hydroselenite monohydrate	10031-39-7
Copper hydroselenite dihydrate	10031-40-0
Copper hydroselenite trihydrate	10031-41-1
Copper(II) hydroxide	20427-59-2 1344-69-0
Copper(II) hydroxyfluoride	13867-72-6
Copper(II) 8-hydroxyquinolate	10380-28-6
Copper(II) hydroxysalicylate	62320-94-9
Copper indium selenide	--
Copper indium sulfide	--
Copper indium telluride	--
Copper(II) iodate	7681-65-4
Copper(I) iodide	13767-71-0
Copper(II) irone(III) oxide	--
Copper(II) lactate	--
Copper(II) linoleate	7721-15-5
Copper malonate	7268-92-0
Copper(II) magnesium sulfate	--
Copper mercaptobenzothiazolate	4162-43-0
Coper(I) mercuric iodide	13876-85-2
Copper methane arsenate	--
Copper(II) methylate	--
Copper(II) molybdate	13767-34-5
Copper(II) naphthenate	1338-02-9
Copper(II) neodecanoate	32276-75-8 50315-14-5 68084-48-0
Copper(II) nickel formate	68134-59-8
Copper(II) nitrate	3251-23-8
Copper(II) nitrate trihydrate	10031-43-3
Copper(II) nitrate hexahydrate	13478-38-1
Copper(I) nitride	1308-80-1
Copper(II) nitride	--
Copper(II) nitroprusside	14709-56-9

Compound	CAS No.
Copper cis-9-octadecenoate	1120-44-1
Copper octanoate	20543-04-8
Copper(II) oleate	1120-44-1 10402-16-1
Copper(II) oxalate	814-91-5
Copper(I) oxide	1317-39-1 1317-38-0
Copper(II) oxychloridesulfate	8012-69-9
Copper(II) palmitate	--
Copper(II) pentamethylene dithiocarbamate	--
Copper peponate	--
Copper(II) perchlorate	13770-18-8
Copper(II) perchlorate hexahydrate	10294-46-9
Copper(II) permanganate	--
Copper(II) phenolsulfonate	547-56-8
Copper(I) phenylacetylide	13146-23-1
Copper 3-phenylsalicylate	5328-04-1
Copper phorphine	13007-96-0
Copper phosphate	7798-23-4 18718-12-2
Copper(II) phosphate, ortho	10103-48-7
Copper(II) phosphate, pyro	10102-90-6
Copper(I) phosphide	12019-57-7
Copper(II) phosphide	12134-35-9
Copper phthalate	--
Copper(II) phthalocyanine	147-14-8
Copper(II) potassium chloride	--
Copper(I) potassium cyanide	13682-73-0 14263-73-1
Coipper potassium hexacyanoferrate(II)	14481-39-1
Copper potassium pyrophosphate	--
Copper(II) potassium sulfate	--
Copper potassium tartrate	--
Copper powder	7440-50-8
Copper(II) propionate	3112-74-1
Copper iso-propoxide	--
Copper proteinate	--
Copper(II) resinate	9007-39-0
Copper b-resorcylate	--
Copper ricinoleate	--
Copper rubidium sulfate	--

Compound	CAS. No.
Copper(II) salicylate	16048-96-7
Copper(II) selenate	15123-69-0
Copper(II) selenate pentahydrate	10031-45-5
Copper(I) selenide	20405-64-5
Copper(II) selenide	1317-41-5
Copper(II) selenite	10214-40-1
Copper(II) silicate	1344-72-5 16509-17-4
Copper silicide	--
Copper(II) sodium chloride	--
Copper(I) sodium cyanide	--
Copper sodium tartrae	--
Copper(II) stannate	12109-07-7
Copper(I) stearate	20563-00-2
Copper(II) stearate	660-60-6
Copper(II) sulfamate	--
Copper(II) sulfate	7758-98-7
Copper(II) pentahydrate	7758-99-8
Copper sulfate, basic	1332-14-5 1344-73-6
Copper(I) sulfate b-naphthol	--
Copper(I) sulfide	22205-45-4
Copper(II) sulfide	1317-40-4
Copper(I) sulfite	13982-53-1
Copper(I) sulfite, monohydrate	10294-49-2
Copper tallate	61789-22-8
Copper(II) tartrate	815-82-7
Copper(I) telluride	12019-52-2
Copper(II) telluride	12109-23-7
Copper(II) tellurite	--
Copper tetramine sulfate	14283-05-7
Copper tetramine sulfate monohydrate	10380-29-7
Copper meso-tetraphenylporphine	--
Copper(I) thiocyanate	1111-67-7
Copper(II) thiocyanate	--
Copper thiourea gold cyanide	68975-64-4
Copper thiophenoxide	--
Copper(II) titanate	12305-89-4
Copper p-toluenesulfonate	--
Copper triethanolamine	--
Copper trifluoroacetylacetonate	--
Copper 3,5,5-trimethylhexanoate	35206-70-3
Copper(II) tungstate	13587-35-4

Compound	CAS No.
Copper undecanoate	7491-40-9
Copper undecylenate	1322-15-2 1328-71-8
Copper(II) vanadate	12789-09-2
Copper m-vanadate	--
Copper zinc chromate	1336-14-7
Copper zinc chromate(VI)	10279-64-8
Copper zinc oxide	--
Copper(II) zirconate	--

APPENDIX B

Table 1. Current Research Projects on Copper and Copper Compounds (ICRDB, 1980; SSIE, 1980; NTP, 1980; NTP, 1981)

Project Title	Nature of Investigation	Investigator/[a] Performing Organization	Source
Frequency of Bronchial Carcinoma Among Employees in a Non-Ferrous Metal Plant	Epidemiologic	Hain, E.F.	ICRDB
Copper Slags	Fibrogenesis	NIOSH, 1980	NTP, 1980
Mortality, Medical, and Industry Hygiene Study of Workers Exposed to Wood Preservatives	Epidemiologic	Tanaka *et al.*	SSIE
Disease and Metal Particulates on Interferon Synthesis	Interferon production	Hahon, N.	SSIE
In Vitro Lung Kinetic Studies	Determine biological availability of inhaled dusts (smelters, mining, etc.)	McCormack, C.	SSIE
Effect of Diesel Exhaust and Diesal Exhaust Components on Rat Lung Determined by the and oxides Aleveolar Protein Accumulation in the Lung	Comparison of metal sulfates	Finelli, V.N.	SSIE
Forums For Copper Smelter Workers on Health and Safety Issues in the Workplace	Occupational safety	Gomez, M.	SSIE
Monitoring Public Health and Animal Health on Farms Receiving Sludge	Epidemiologic monitoring	Dorn, C.R.	SSIE
Damage to DNA Synthesis by Trace Metals and Hydrocarbons	*In vitro* testing	Popenoe, E.A.	SSIE

Table 1. Current Research Projects on Copper and Copper Compounds (ICRDB, 1980; SSIE, 1980; NTP, 1980; NTP, 1981) (Cont'd)

Project Title	Nature of Investigation	Investigator/[a] Performing Organization	Source
Ultrastructure and X-Ray Microanalysis of Macrophages Exposed to Noncriteria Pollutants With Emphasis on Certain Metal Compounds	Biological availability/ subcellular reactions	Shelburne, J.D.	SSIE
Determination of the Impact of Proximal Living to Zn, Cu, and Pb Smelters on the Trace Metal Burdens of Persons of Varying Ages	Epidemiologic monitoring	Handy _et al_.	SSIE
Toxicity of Abrasive Blasting Materials	Toxicity of respirable dusts (rats)	Mackay, G.	SSIE
Carcinogenic Factors in Smelter Dust	Identify potentially carcinogenic inorganic compounds in copper smelter dust (rats)	Lal and Brewer	SSIE
Mortality of Metal Miners in United States	Epidemiology	Costello, J.	SSIE

[a] Detailed information on performing organization and sponsoring organization is presented in the list of references under the name of the investigator.

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2123/10

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