JEWELRY MANUFACTURING

I. SCOPE OF PROFILE

The purpose of this profile is to review the processes used in manufacturing jewelry in order to identify the potential occupational hazards associated with the industry. The profile is drawn from a limited number of sources, and should be regarded only as a summary of jewelry manufacturing practices, and not as a comprehensive review.

Jewelry manufacturing, Standard Industrial Classification Group No. 391, is defined as the production of jewelry and other articles worn on or carried about the person. The industry includes objects made of precious metals, with or without stones (SIC 3911); silverware, plated ware, and stainless steel ware including products made of sterling silver, metal plated with silver, gold, nickel, pewter, or other metal (SIC 3914); and jewelers' findings (small unassembled, unfinished jewelry parts) and lapidary work including the cutting, slabbing, tumbling, carving, engraving, and faceting of stones and gems (SIC 3915). Full descriptions of these SIC categories are presented in Appendix A.

II. SUMMARY

Jewelry is manufactured by stamping, or by die, lost wax, or rubber mold casting. The pieces are assembled mechanically, or by soldering, epoxying, or gluing. Finishing processes include degreasing, cleaning, electroplating, and polishing and buffing. Finally, jewelry may be lacquered, enameled, or adorned with plastic embedments. Hazards to the worker result primarily from exposure to various chemicals compounds during casting, soldering, electroplating, and finishing operations.

III. STATISTICAL INFORMATION

The number of workers employed in the jewelry industry, as well as the number of establishments, is detailed in Table 1. In 1976, the total number of jewelry establishments was 2459, with the majority producing precious metal jewelry (Bureau of the Census, 1978). Of the 56,500 people employed by the industry, more than 60% worked in establishments of ten or fewer employees. Injury and illness incidence rates for the industry are also presented in Table 1; as indicated, the rates are generally lower than the average values for all U.S. manufacturing facilities.

IV. PRODUCTION AND TRENDS

The jewelry industry is characterized by small, close-knit production units. The precious jewelry industry is centered in the New York City area, while the low- and medium-priced jewelry industry is concentrated in the greater Providence, Rhode Island and Attleboro, Massachusetts areas.

As detailed in Table 1, the total value of jewelry shipped in 1976 was greater than 2.6 billion dollars (Bureau of the Census, 1979).

V. CHARACTERIZATION OF PROCESSES

The information in this section was compiled from Martin (1978) and Frankovich (1955). The processes of jewelry manufacture vary greatly according to the quality of the merchandise being produced. The greater the cost of materials, the more pronounced the trend toward lesser mechanization, and the higher the degree of skill required. Exceptions are products such as expansion bands which contain various mechanisms. Individual plants vary from those that are totally self-contained to those that are termed "manipulators" and merely assemble pieces purchased from findings shops.

Table 1. Jewelry Industry Statistical Information

SIC No.	3911	3914	3915	391	
No. of Establishments[a]	1,678	211	564	2,459	
No. of Employees[b]	40,800	9,000	6,700	56,500	
No. of Production Workers[b]	28,000	6,800	5,500	41,100	
Value of Shipment ($\$10^{6}$)[b]	\$ 1,766.5	397.6	527.1	2,691.3	
Employment Size per Production Unit[a]					
% Below 5 employees	43	35	52	44	
10 employees	62	54	70	64	
20 employees	80	70	83	80	
50 employees	91	84	93	91	
100 employees	96	91	98	96	
Over 100 employees	4	9	2	4	
Rates for Injury & Illness for 1977[c]					
Cases per 100 full-time workers					All U.S. Manufacturing
Total cases injury & illness	4.6	9.9		6.1	13.1
Total cases injury	4.1	9.3		5.6	12.6
Total cases illness	0.5	0.6		0.5	0.5
Lost work day cases	1.4	5.0		2.2	5.2
Lost workdays	17.2	86.0		32.9	82.3

[a] Bureau of the Census, 1978 (1976 data)
[b] Bureau of the Census, 1979 (1976 data)
[c] Bureau of Labor Statistics, 1979

There are two basic methods of jewelry manufacture: stamping and casting. Convenience, economics, and the type of piece to be produced determine which method is preferred.

Stamping, or mechanical working of flat stock, wire, and tubing, includes the handwork skills of the platinumsmith and goldsmith. Mechanical methods include the use of power presses, drop hammers, and punch and foot presses. Metals used in mechanical jewelry production are platinum, gold, silver, gold filled and rolled gold plate, brass, steel, and nickel.

In casting, molten metal is ladled into molds in casting machines. This mode of production permits greater versatility and variation in the design of jewelry, but offers the greatest potential for worker exposure to fumes. Metals used include gold, silver, brass, tin, zinc-aluminum, and lead. There are three types of casting: die, lost wax, and rubber mold casting.

In lost wax casting, also called investment casting, plaster is molded around a wax model. After the plaster hardens, it is placed in a furnace and the wax is melted away, leaving the plaster mold. Brass and bronze are cast by this method.

Rubber molds are used in the costume jewelry industry for the casting of low temperature metals (400-700°F). White metals--which contain large amounts of tin and lead, and smaller amounts of antimony, nickel, copper, or zinc--are most commonly used. Talc is often dusted onto the molds before casting to prevent sticking. After casting and hardening, the mold and cast are separated in a breakdown operation. The potential for toxic exposure to metal fumes during melting and pouring operations is less than in other types of casting because the metals are not heated to exceptionally high temperatures.

After production of the ornaments or findings, the pieces are assembled. This may be accomplished mechanically with rivets, screws, and springs, by soldering, or by epoxying and gluing. Soldering, the brazing or welding of one piece to another, is performed either by hand torch or by machine. Hard solders, such as gold and silver, or soft industrial solders, such as lead and tin, may be used. In epoxying and gluing, workers use resins prepared from epichlorohydrin and a polyhydroxy compound (e.g., bisphenol A) in the presence of polyamine hardening agent.

The finishing of metal jewelry consists of several operations, which include degreasing, cleaning, electroplating, and polishing and buffing. In mass finishing, also known as tubbing or deburring, automatic equipment is used to smooth out jewelry by vibration, rotation, or other means.

Jewelry is cleaned and degreased in solvent vapors or acid or alkali baths. The most commonly used solvents are trichloroethylene and perchloroethylene. Use of carbon tetrachloride has declined since its adverse health effects have become known, and many manufacturers are changing over to stabilized chlorinated solvents such as 1,1,1-trichloroethane. The solvents are typically heated by a coil, and the jewelry suspended in the vapors for cleaning. Acid cleaning, also known as "bright dripping," uses baths of hydrofluoric, hydrochloric, sulfuric, nitric, or chromic acids. Sprays or baths of ammonia or caustic soda (sodium hydroxide) are used in alkali cleaning.

Electroplating is the process by which one metal is deposited on another by the passing of a current through an electrolyte. Plants may use automatic or semi-automatic systems. Copper, nickel, and precious metals are the major metals used for electroplating, and jewelry made of brass, tin, or other base metals is most commonly electroplated. Bimetallic products (gold filled or rolled gold plate) are also commonly electroplated, both to color the jewelry and to hide any raw edges. Inexpensive jewelry and novelty items may be lightly electroplated (known as dipping or coloring) or vacuum plated, in which the object is thinly coated with colored aluminum.

Polishing and buffing may be done by machine or by hand. The latter method utilizes a wheel covered with canvas, muslin, or felt. Various abrasives, such as ground silica, aluminum oxide, soft silica, silicon carbide, and chromium oxide powder, are applied to the cloth.

Jewelry may be lacquered, enameled, or decorated with plastic embedments. Lacquering and enameling operations employ the use of solvents such as methyl ethyl ketone.

VI. ENGINEERING CONTROLS

Engineering controls vary greatly among jewelry manufacturing plants.

Toxic solvent exposures may result from casting operations, and from degreasing apparatuses that are not properly designed, maintained, or located (Martin, 1978). Solvent vapors should not be allowed to rise above the top edge of degreasing tanks (controllable by the use of condensers and thermostats), and degreasers should not be located near cross drafts, dead space exhaust systems, or open flames.

If the ladles used in casting room operations are not preheated before use, condensation can occur. This may result in a rapid expansion of the metal molecules, and a consequent explosion (heat and burn exposure) potential.

The use of automated or semi-automated systems may minimize potentially hazardous exposures, particularly in the electroplating operations.

There is a lack of standard safety guards for certain types of machines, particularly those used in the watch-making industry (Martin, 1978). The greatest potential hazard to tubbing workers, that of catching hands or arms in the equipment (Martin, 1978), is controllable by the use of microswitches which automatically stop all machinery motion whenever lids are opened.

Noise hazards may be reduced by the installation of acoustical panels and by requiring workers to wear ear protection.

Poor worker hygiene also contributes to workplace hazards. The body may be exposed to toxic substances via contaminated hands, food, or cigarettes (Martin, 1978).

VII. POTENTIAL HEALTH HAZARDS

Workers in the jewelry manufacturing industry may be exposed to a number of potentially toxic substances, and the cleaning and degreasing, and electroplating operations are among the most hazardous. Many of these substances are identified in Tables 2 and 3, along with the primary sources and manufacturing processes with which they are associated. A summary of the principal toxic effects of these compounds is presented in Table 4. It must be emphasized that the information presented in these tables is derived from an extremely cursory review of the literature, and that the overviews are neither critical nor comprehensive.

A recent report suggests that cadmium intoxication may be a significant problem in certain groups of workers. In a study by Baker and coworkers (1979), thirty-six workers in a small, Arizona plant that manufactured handmade silver jewelry were examined for cadmium toxicity following complaints of unusual symptoms. Twenty-three of the workers used a brazing alloy containing 15.6% cadmium, 29.3% silver, 10.4% zinc, 9.8% copper, and 35% fluoride-containing flux which generated cadmium oxide fumes when heated. Analyses of blood, hair, and urine indicated elevated levels of cadmium, but the usefulness of these as indicators of toxicity varied. Blood cadmium levels were found

Table 2. Hazards Associated with Jewelry Manufacturing Processes (Martin, 1978)

Process	Hazards
Stamping	Lack of standard safety guards for certain types of heavy machinery. Noise.
Casting	Dermatitis. Heat exposure and burns from condensation of hot metal on non-preheated ladles.
a) Die	Exposure to metal fumes.
b) Lost Wax	Inhalation of silica dust from plastic molds.
c) Rubber Mold	Inhalation of talc dust, which may contain silica or asbestos. Ingestion or inhalation of lead dust from contaminated molds.
Mass Finishing	Danger of catching body parts in the tubbing machinery.
Degreasing	Exposure to solvents, usually trichloroethylene or perchloroethylene, and sometimes carbon tetrachloride or stabilized chlorinated solvents. Improper regulation of degreaser temperatures may result in production of phosgene from decomposition of solvents. In alkali and acid cleaning, exposure to liquids, fumes, mists, or dusts. Exposure to arsine gas may occur when metal containing arsenic is treated with acid.
Electroplating	Heat exposure. Chemical or thermal burns. Skin irritation from acids, cyanides, and metal salts. Inhalation and dermal absorption of hydrogen cyanide if cyanide salts come into contact with acids. Exposure to cobalt and selenium.
Polishing and Buffing	Inhalation of abrasives, particularly silica compounds, from polishing wheel. Irritation of skin or eyes from adhesives used on wheels. Dermatitis from metal dusts.
Soldering	Inhalation of fumes containing fluorides, lead, and cadmium. Exposure to asbestos used in heat-resistant boards.
Epoxying and Gluing	Inhalation of resins prepared from epichlorohydrin.
Lacquering and Enameling	Exposure to solvents such as methyl ethyl ketone.
Embedding of Plastics	Hazards similar to those of the plastics industry.

Table 3. Principal Use and Sources of Chemicals in the Jewelry Manufacturing Industry (Martin, 1978)

Chemical	Principal Uses/Sources
Aluminum	Electroplating. Alloy production. Aluminum oxide used as abrasive on polishing and buffing wheel.
Ammonia	Used in degreasing operations. Jewelry is sprayed or soaked in baths.
Antimony	Component of white metal.
Arsenic	Trace amounts may be found in copper alloys. Arsine gas may form in degreasing, when metals containing trace amounts of arsenic (e.g., zinc, copper, and white metal) are treated with an acid.
Asbestos	Component of many talc powders. Soldering done on asbestos boards, many of which are made in-house from powdered asbestos.
Beryllium	Grinding up of casts, drilling, or machine operations in tool room. Trace amounts may be found in copper alloys.
Cadmium	Soldering compounds. Electroplating.
Carbon tetrachloride	Used in some shops as a degreaser and to clean molds after casting.
Caustic soda	Used in degreasing operations. Jewelry is sprayed or soaked in baths.
Chromic acid	Baths are used in degreasing operations.
Chromium	Copper etching, chrome plating, production of stainless steel. Chromium oxide powder used as abrasive on polishing wheel.
Cobalt	Added to electroplating baths to improve luster of metal.
Copper	Used in electroplating (copper sulfate and cyanide), jewelry and alloys, soldering and by gem colorers. Component of white metal. Exposure may also result from the casting of brass and bronze.
Cyanide salts	Sodium cyanide and copper cyanide used for copper plating.
Epichlorohydrin	Hardening agent found in resins used in epoxying and gluing.
Fluorides	Solder fluxes.
Gold potassium cyanide	Used for precious metal electroplating.
Hydrogen cyanide	Used in electroplating. Also from accidents in preparation, handling, or storage of chemicals, or if acid and cyanide fumes are vented into a common duct.

Table 3. Principal Uses and Sources of Chemicals in the Jewelry Manufacturing Industry (Martin, 1978) (cont'd)

Chemical	Principal Uses/Sources
Hydrochloric acid	Component of acid-gold solutions used in electroplating. Baths are used in degreasing solutions.
Hydrofluoric acid	Baths are used in degreasing operations.
Lead	Soldering compounds. Major component of white metal. Rubber mold casting pots may be a source of lead oxide, and the molds may become contaminated with excess lead dust.
Mercury	Used in gold, silver, bronze and tin plating, and in soldering.
Methyl ethyl ketone	Used as solvent in lacquering and enameling.
Nickel	Production of alloys including stainless steel. Component of white metal, nickel sulfate, and nickel chloride used in electroplating.
Nitric acid	Baths are used in degreasing operations.
Perchloroethylene	Used as solvent in cleaning and degreasing operations.
Phosgene	Produced by thermal decomposition of chlorinated solvents used in degreasing which may occur if temperature of degreaser is not properly regulated.
Phosphoric acid	Component of acid-gold solutions used for electroplating.
Platinum	Electroplating.
Potassium cyanide	Used in silver electroplating.
Rhodium	Used in electroplating.
Selenium	Added to electroplating baths to improve luster of metal.
Silica	Constitutes up to 30% of lost wax molds. Component of many talc powders. Ground and soft silica and silicon carbide used as abrasives for polishing and buffing wheels.
Silver	Manufacture of alloys, silverware, jewelry, ornaments. Found in solders. Silver cyanide is used in silver electroplating.
Sodium cyanide	Used in cyanide-copper electroplating.
Sulfuric acid	Used in metal pickling processes. Baths used in degreasing operations.
Talc	Manually dusted on rubber mold casts to prevent jewelry piece from sticking.

Table 3. Principal Uses and Sources of Chemicals in the Jewelry Manufacturing Industry (Martin, 1978) (cont'd)

Chemical	Principal Uses/Sources
Tellurium	Manufacture of silverware.
Thallium	Manufacture of imitation precious jewelry.
Tin	In soft solders, coating of silverware, pewter, bronze and other alloys, electroplating baths. Major component of white metal.
1,1,1-Trichloroethane	Used as solvent in degreasing operations.
Trichloroethylene	Used as solvent in cleaning and degreasing operations.
White Metal	Any of several light-colored alloys used as a base for plated silverware and jewelry. Usually contain large amounts of tin and lead, and smaller amounts of antimony, nickel, copper, or zinc.
Zinc	Component of white metal. Zinc chloride used in soldering compounds.

Table 4. Toxicological/Physiological Properties of Chemicals Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977)

Chemical	Acute	Chronic
Aluminum Compounds	Acids liberated from aluminum salts by hydrolysis may cause eczema, dermatoses, conjunctivitis, and irritation of the mucous membranes of the upper respiratory system.	Inhalation of dusts or fumes may cause pneumoconiosis; however, in most cases, workers were exposed to other materials as well.
Ammonia	Liquid and aqueous solutions intensely irritating to eyes, skin, and mucous membranes. Gas irritates eyes and skin, and may produce headache, salivation, burning of throat, anosmia, perspiration, nausea, vomiting, and substernal pain. More severe exposure causes severe irritation of the respiratory tract, with coughing, glottal edema, broncho-spasm, pulmonary edema, or respiratory arrest. If the patient survives severe exposure, bronchitis or penumonia may follow.	No important effects.
Antimony	Target organs of inhaled dust or fumes are the heart, lungs, the mucous membrane of the respiratory tract, and protein and carbohydrate metabolism enzyme systems. Antimony is a primary skin irritant, producing lesions on exposed, moist areas.	Chronic oral poisoning produces symptoms of dry throat, nausea, headache, sleeplessness, loss of appetite, dizziness, and, later, liver and kidney degenerative changes.
Arsenic	Fumes and dust irritate nose, causing nosebleeds and perforation of the nasal septum. Also irritate eyes, producing corneal damage. Corrodes skin. Exposure to arsine gas may result in severe headache, faintness, and severe digestive disturbances.	Causes lung cancer. Produces changes in the blood, kidneys, and nervous system. Arsine gas may cause heart, brain, kidney, or liver damage.
Asbestos	No important effects.	Bronchogenic carcinoma and mesothelioma of the pleura and peritoneum are caused by exposure to fibers. Excesses of cancer of the stomach, colon, and rectum have also been seen. Mesothelioma may occur after short, intensive exposure. Asbestos is a progressive lung disease characterized by a diffuse interstitial fibrosis.

Table 4. Toxicological/Physiological Properties of Chemicals Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977) (Cont'd)

Chemical	Acute	Chronic
Beryllium	Effects of inhaling beryllium fumes range from inflammation of nose and throat to severe pneumonitis. Salts irritate and and sensitize skin.	Chronic beryllium disease affects the lungs and, often, the liver, spleen, heart, skin, kidneys, and bones. Condition may not appear until years after exposure. Has been known to lead to cancer.
Cadmium	Exposure to dusts and fumes leads to a chemical pneumonia. Symptoms include chest pain, labored breathing, and edema, and continue after exposure ceases. Compounds absorbed well by inhalation, poorly through digestive tract. Retained in kidney and liver. Long half-life in body.	Emphysema, renal disease decalcification of bones, and, possibly carcinoma of the lung and prostate. In experimental animals, cadmium exposure has produced liver and central nervous system damage, testicular atrophy, decrease in total red blood cells, sarcomata, testicular neoplasms, and teratogenic effects after intraveneous injection.
Carbon Tetrachloride	Symptoms of liver and kidney damage. Death may result from acute renal failure. Ingestion of alcohol increases effects.	Rodents developed liver tumors following several routes of administration, including inhalation and ingestion.
Chromic Acid	Mist severely irritates the nasopharynx, larynx, lungs, and skin.	In electroplating, workers may experience lacrimation, inflammation of the conjunctiva, nasal itch and soreness, epistaxis, ulceration and perforation of the nasal septum, conjested nasal mucosa and turbinates, chronic asthmatic bronchitis, dermatitis and ulceration of the skin, inflammation of laryngeal mucosa, cutaneous discoloration, and dental erosion. Rarely, exposure to chromic acid in plating baths has caused hepatic injury.
Chromium	Metal and insoluble salts relatively nontoxic. Trivalent salts readily absorbed through skin. Effects such as contact dermatitis, skin ulcers, irritation and ulceration of the nasal mucosa and perforation of the nasal septum may result from contact with many Cr (IV) compounds; kidney and liver damage, pulmonary congestion and edema, epigastric pain, erosion and discoloration of the teeth, and perforated eardrums have been reported on occasions.	Some chromium (VI) compounds have been associated with an increased incidence of lung cancer.

Table 4. Toxicological/Physiological Properties of Chemical Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977) (Cont'd)

Chemical	Acute	Chronic
Cobalt	Minute quantities may cause allergic sensitivity type dermatitis. Eruptions appear in flexure creases of elbows, knees, ankles, and neck. Cross sensitization may occur with nickel and chromium.	Inhalation may produce asthma-like disease with cough and dyspnea. May progress to interstitial pneumonia with marked fibrosis and reversible pneumoconiosis.
Copper Compounds	Inhalation of copper oxide may induce metal fume fever, a 24 to 48 hour illness with influenza-like symptoms. Occasionally, inhalation of dusts, fumes, or mists of copper salts may cause ulceration and perforation of the nasal septum. Salts irritate the gastrointestinal tract, producing salivation, nausea, vomiting, hemorrhagic gastritis, and diarrhea.	No important effects.
Cyanide Salts	Sodium cyanide, potassium cyanide, and copper cyanide are corrosive to the skin, eyes, and mucous membranes. In contact with acid, the salts form hydrogen cyanide gas (see Hydrogen Cyanide). Cyanide ion inhibits many enzymes, the most sensitive being cytochrome oxidase. Death may result from chemical asphyxia at the cellular level.	No important effects.
Epichlorohydrin	Strong irritant, causing asthma-like bronchiospasm and coughing. Symptoms of exposure include nausea, vomiting, abdominal discomfort, labored breathing, cough, and cyanoses. Chemical pneumonitis may develop several hours after exposure.	Lung, liver, and kidney injuries have developed in animals. It is carcinogenic in mice by subcutaneous injection (producing local sarcomas), active as an initiator in a two-stage skin carcinogenesis in mice, and has induced chromosomal effects in rodent and human cells.
Fluorides	Ingestion produces symptoms which include nausea, vomiting, abdominal cramps, and diarrhea. Large doses may result in central nervous system involvement with twitching of muscle groups, tonic and clonic convulsions, and coma.	Retained preferentially in bone; may result in osteosclerosis, with some ossification of ligaments. First sign of density changes appear in the lumbar spine and pelvis. Rather severe skeletal fluorosis may occur without any physiological effects.
Gold Potassium Cyanide	Corrosive to skin, eyes, and mucous membranes.	No important effects.

Table 4. Toxicological/Physiological Properties of Chemicals Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977) (Cont'd)

Chemical	Acute	Chronic
Hydrogen Cyanide	Inhalation of gas causes headaches and nausea. Severe cases result in death.	No important effects.
Hydrochloric Acid	Vapors strongly irritate the mucous membranes of the nose and throat, causing coughing or choking. Liquid splashed in face results in ulceration of the eyes or mucous membranes. In workers, short exposure to 35 ppm caused irritation of the throat. Acclimatization may occur with chronically exposed workers.	Erosion of exposed teeth.
Hydrofluoric Acid	Gas is severe respiratory irritant. Inhalation produces choking and coughing. After an asymptomatic period of one to two days, fever, cough, dyspnea, cyanosis, and pulmonary edema may develop. Liquid severely and painfully burns skin. Fluoride ion readily penetrates skin and deep tissue, causing necrosis of soft tissues and decalcification of bone.	Human exposure to 2.6 to 4.8 ppm for up to 50 days caused slight irritation of nose, eyes, and skin, but no signs of pulmonary irritation. Excessive exposure over a period of years results in increased radiographic density of bone, perhaps with crippling osteosclerosis. Density changes first apparent in the lumbar spine and pelvis.
Iron	Exposure to oxide may result in metal fume fever, a 24 to 48 hour illness with influenza-like symptoms.	Inhalation of fumes or dust may cause a benign pneumoconiosis (siderosis).
Lead	Inhalation of oxide may produce headache, weakness, abdominal pain, muscular cramps, loss of appetite, or nausea. In larger quantities, may cause severe gastrointestinal, blood, and central nervous system disorders. Metal splinters may irritate skin.	Anemia and lead line on the gums. Later, wrist drop. After long periods, may cause loss of kidney function and progressive azotemia. Lead accumulates in the body.
Mercury	Vapors primarily affect lungs, causing interstitial penumonitis, bronchitis, and bronchiolitis. Larger exposures may produce irritability, excitability, delirium, anxiety, melancholia, or manic depressive psychosis.	There are four classical symptoms of chronic mercury intoxication: ginginvitis, sialorrhea, increased irritability, and muscular tremors. These signs are rarely all present in a single individual.

Table 4. Toxicological/Physiological Properties of Chemicals Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977) (Cont'd)

Chemical	Acute	Chronic
Methyl Ethyl Ketone	Irritates eyes, mucous membranes, and skin. High concentrations (10,000 ppm) produce narcosis in animals. Irritating acetone-like odor detectable at 25 ppm. 100 ppm caused slight nose and throat irritation in workers.	Dermatitis results from repeated exposure to liquid and, more rarely, vapor.
Nickel Compounds	Nickel sulfate and chloride are strong skin irritants. Produces "nickel itch," a contact dermatitis which begins in the hands and arms, but may spread to the entire body. Compounds also irritate conjunctiva of eye and mucous membranes of respiratory tract.	Probably carcinogenic to lungs and nasal passages. Animal studies report effects on heart muscle, brain, liver, and kidney.
Nitric Acid	Liquid is extremely corrosive and may cause severe burns, ulcers, and necrosis of the skin, mucous membranes, and eyes. High concentrations of vapor or mist produce pneumonitis and pulmonary edema. Onset of symptoms may be delayed 4 to 30 hours after exposure.	Low level exposure to gas may cause yellowish or brownish staining of skin and teeth. Vapor and mist may erode exposed teeth.
Perchloroethylene (Tetrachloroethylene)	Strong narcotic. Effects range from mild narcosis to respiratory arrest and death.	Permanent liver damage. Dry, scaly, and fissured dermatitis.
Phosgene	Pulmonary edema, frequently following a latent period of 5 to 12 hours. Death may result from respiratory or cardiac failure. At low levels (205 mg/cu m), phosgene produces no warning symptoms.	May result in irreversible pulmonary changes of emphysema and fibrosis. May cause some tolerance to acute edemagenic doses.
Phosphoric Acid	Mist is a mild irritant of the eyes, upper respiratory tract, and skin. Dust irritates skin in the presence of moisture. Unacclimated workers found concentrations of 0.8 to 5.4 mg/cu m of fumes of phosphorous pentoxide (the anhydride of the acid) noticeable but not uncomfortable. 3.6 and 11.3 mg/cu m produced coughing, and exposure to 100 mg/cu m was unendurable.	No important effects.

Table 4. Toxicological/Physiological Properties of Chemicals Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977) (Cont'd)

Chemical	Acute	Chronic
Platinum	Complex salts sensitize the skin, nasal mucosa, and bronchi, and cause allergic reactions.	Symptoms occur after 2 to 6 months' exposure, and include pronounced irritation of the throat, of nasal and bronchial passages, and of the skin. Status asthmaticus may develop. After recovery, exposure to minimal amounts of platinum may produce allergic symptoms, including dermatitis, and asthma attacks.
Rhodium	Solutions of soluble salts splashed in the eye may cause minor irritation. Studies of humans and animals have not found any toxic effects of metal fumes or dusts; the intravenous LD_{50} for rhodium trichloride in rabbits is 215 mg/kg. The rapid onset of death suggested central nervous system effects.	No important effects.
Selenium	Irritates eyes, mucous membranes, and skin.	Essential trace element for rats and chickens, and probably for humans.
Silica Compounds	Inhalation of large amounts results in coughing, dyspnea, and weight loss.	Silicosis, a type of fibrosis which is progressive and disabling.
Silver	No important effects.	Argyria: local or generalized impregnation of the mucous membranes, skin, and eyes with silver. All forms of silver are extremely cumulative in the body.
Sodium Hydroxide (Caustic Soda)	Contact with the solid or concentrated solutions severely irritates the eyes, mucous membranes, and skin, rapidly destroying tissues. Inhalation of 2 mg/cu m mildly irritates the nose. Larger amounts may produce severe pneumonitis. Ingestion causes severe abdominal pain, corrosion of the lips, mouth, tongue, and pharynx, and vomiting of large pieces of mucosa.	Cases of squamous cell carcinoma of the esophagus have occurred 12 to 42 years after ingestion. Thought to be caused by previous cell destruction and possible scar formation rather than to any carcinogenic action of sodium hydroxide.

Table 4. Toxicological/Physiological Properties of Chemicals Encountered in Jewelry Manufacturing (Martin, 1978; Proctor and Hughes, 1978; NIOSH, 1977) (Cont'd)

Chemical	Acute	Chronic
Sulfuric Acid	Severly irritates mucous membranes of nose and throat, causing coughing and choking. Erodes teeth. Burns skin.	Bronchitic symptoms, rhinorrhea, lacrimation, and epistaxis. May result in conjunctivitis, frequent respiratory infections, emphysema, and digestive disturbances.
Talc	No important effects.	Development of small nodular areas in the lungs proportional to the amount of deposited dust. Some talcs contain silica and asbestos.
Tellurium	Relatively low toxicity. Inhalation of fumes may cause foul breath and perspiration, metallic taste in the mouth, dryness, afternoon somnolence, and loss of appetite. Hydrogen telluride had central nervous system, respiratory, and cardiac effects.	Metallic tellurium was teratogenic in tests on rats.
Thallium	Ingestion produces gastrointestinal symptoms, loss of kidney function, peripheral neuritis, strabismus, disorientation, convulsions and alopecia. Death is due to central nervous system damage.	Neurological signs may predominate in chronic severe poisoning. Other symptoms include optic atrophy, para-esthesias, and slowed pupillary and superficial tendon reflex responses.
Tin	Splinters may irritate skin. Some inorganic salts mildly irritate eyes and mucous membranes.	Dust or fumes may cause stannosis, a benign pneumoconiosis.
1,1,1-Trichloroethane	Cardiac effects in high concentrations. Acts as narcotic and depresses the central nervous system. Liquid and vapor irritate eyes.	Repeated skin contact may cause dermatitis.
Trichloroethylene	Irritates eyes, nose, and throat. Depresses central nervous system. Alcohol increases the symptoms of trichloroethylene exposure.	Addiction and peripheral neuropathy have been reported. May induce liver tumors in mice.
Zinc Compounds	Metal splinters may irritate the skin. Oxide may cause metal fume fever, a 24 to 48 hour illness with influenza-like symptoms.	No important effects.

to be nearly 2.5 times greater in exposed workers than in unexposed workers (0.93 μg/100 ml and 0.38 μg/100 ml, respectively), and seemed to accurately reflect levels of cadmium exposure and to correlate well with symptoms of cadmium intoxication. For four symptoms (dyspnea, chest pain, dizziness, and dysuria), a dose-response relationship with cadmium blood levels was observed. Levels of cadmium in hair were determined to be highest (up to 19 μg/g) in sections farthest from the scalp and in hair formed prior to cadmium exposure, suggesting that external contamination by cadmium fumes was the primary source of exposure.

Hazardous mercury exposure was associated with several jewelry molding operations in Australia and New Zealand in the 1960's (Copplestone and McArthur, 1966; Jones and Longley, 1966). In these facilities, jewelry was manufactured by processes similar to the lost wax method (Section V) except that, instead of wax, low melting point alloys of mercury and cadmium were used in the initial molding operation. Considerable exposure to mercury vapor occurred, as evidence by measured air concentrations (up to 35 mg/m^3), and urinary concentrations (up to 3.7 mg/l). In many cases, the higher urinary levels were associated with molding and the oven melting of the alloy from the molds. Despite the high urinary and atmospheric mercury levels, the workers for the most part did not exhibit any overt indications of poisoning; of 36 employees surveyed in one study (Jones and Longley, 1966), only one showed definite symptoms of mercurialism, while others exhibited vague changes. The installation of effective local exhaust ventilation served to control the mercury problems, and the cadmium portions of the alloys did not appear to constitute an exposure problem.

Lead poisoning in jewelry enamelers in Birmingham, England has been reviewed by Fothergill and coworkers (1967). The hazard, principally of historical interest, arises from the habit of some workers, primarily female, of placing the enamel applicator in the mouth (mouth pointing) and was first reported at the beginning of the century in a survey of 85 enamelers. The enamel frit used in the process is typically a lead-borosilicate containing about 42% lead. No more cases were reported until 1962, when a single diagnosis was made; following this incident, a survey of 223 jewelry enamelers was undertaken (Chalmers et al., 1963).

The results of this survey revealed three further cases of lead poisoning with marked anemia and abdominal symptoms (Fothergill et al., 1967). Mouth pointing was practiced regularly by 18% of the enamelers, and another 40% practiced it occasionally. Of the regular mouth pointers, 35% had hemoglobin levels below 12 g/100 ml and 20% showed excess urinary porphyrins; in the group that did not mouth point, 10.5% had hemoglobin levels below 12 g/100 ml and none showed excess urinary porphyrins. Following this survey, an additional case of lead poisoning in an enameler was reported (Fothergill et al., 1967).

VIII. PERTINENT NIOSH PUBLICATIONS

A. Criteria Documents

Subject	NIOSH Publication No.
Ammonia	74-136
Asbestos	72-10267
Asbestos (revised)	77-169
Beryllium	72-10268
Cadmium	76-192
Carbon Tetrachloride	76-133
Chromic Acid	73-11021
Chromium (VI)	76-129
Crystalline Silica	75-120
Epichlorohydrin	76-206
Inorganic Arsenic	74-110
Inorganic Arsenic (revised)	75-149
Inorganic Fluoride	76-103

Subject	NIOSH Publication No
Inorganic Lead	73-11010
Inorganic Mercury	73-11024
Inorganic Nickel	77-164
Nitric Acid	76-141
Phosgene	76-137
Sodium Hydroxide	76-105
Tetrachloroethylene (Perchloroethylene)	76-185
1,1,1-Trichloroethane	76-184
Trichloroethylene	73-11025
Zinc Oxide	76-104

B. Health Hazard Evaluations (HHE's)

No health hazard evaluation of jewelry manufacturing operations were encountered.

C. Other NIOSH Publications

Title	NIOSH Publication No.
Health and Safety Guide for Electroplating Shops	75-145
Health and Safety Guide for Metal Stamping Operations	75-174
How to Get Along With Your Solvent	76-108
Epoxy Wise is Health Wise	76-152
Spray Painting - Good Practice for Employees	76-178
Working with Industrial Solvents (folder)	77-139
Good Work Practices for Electroplaters	77-201

IX. EXISTING STANDARDS

A listing of ACGIH Threshold Limit Values (TLVs), OSHA promulgated standards, and NIOSH recommended criteria is presented in Table 5.

X. EXPOSURE ESTIMATES

As detailed in Section III and Table 1, approximately 56,500 people were employed in the jewelry industry in 1965; of this total, 41,000 were production workers.

XI. ONGOING STUDIES

No ongoing studies pertaining to occupational health hazards associated with the jewelry manufacturing were encountered.

Table 5. Threshold Limit Values, OSHA Promulgated Standards, and NIOSH Recommended Criteria*

Chemical	TLV (ACGIH, 1977)		OSHA (OSHA, 1976)		NIOSH (1978)	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Aluminum						
metal and oxide	---	10	---	---	---	---
fumes	---	5	---	---	---	---
Ammonia	25	18	50	---	50 (5-minute ceiling)	34.85 (5-minute ceiling)
Antimony	---	0.5	---	0.5	---	0.5
Arsenic	---	0.5	---	0.5	---	0.002 (15-minute ceiling)
Asbestos	5 fibers/cm^3, >5μ in length		2 x 10^6 fibers/m^3 1 x 10^7 fibers/m^3 (ceiling)		100,000 fibers/m^3, >5μ 500,000 fibers/m^3, >5μ (15-minute ceiling)	
Beryllium	---	0.002	---	0.002 0.005 (acceptable ceiling) 0.025 maximum ceiling (30-minute)	---	0.005 (130-minutes)
Cadmium	---	---	---	---	---	.040 .200 (15-minute ceiling)
dust and salts	---	0.05	---	0.2 0.6 (ceiling)	---	---
oxide fume	---	0.05	---	0.1 0.3 (ceiling)	---	---

*All values are 8-hr TWA concentrations, except as indicated; NIOSH limits are based on up to a 10-hr exposure.

Table 5. Threshold Limit Values, OSHA Promulgated Standards, and NIOSH Recommended Criteria* (Cont'd)

	TLV (ACGIH, 1977)		OSHA (OSHA, 1976)		NIOSH (1978)	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Carbon Tetrachloride	10	65	10 25 (acceptable ceiling) 200 (maximum ceiling; 5-minutes in four hours)		2 (60-minute ceiling)	12.6 (60-minute ceiling)
Chromium						
Chromic Acid	---	0.05	---	.1 (ceiling)	---	0.05 0.1 (15-minute ceiling)
Chromium (VI)	---	0.05 (chromates)	---	10 (ceiling)	---	0.001 (carcinogenic) 0.025 (other) 0.050 (15-minute ceiling)
Soluble Chromic, chromous salts	---	0.5	---	---	---	---
Cobalt metal, dust, and fumes	---	0.05	---	---	---	---
Copper fumes	---	0.2	---	---	---	---
Dusts and Mists	---	1	---	---	---	---
Cyanide	---	5	10 (alkali cyanides)	5	4.7 (10-minute ceiling)	5 (10-minute ceiling)

Table 5. Threshold Limit Values, OSHA Promulgated Standards, and NIOSH Recommended Criteria* (Cont'd)

	TLV (ACGIH, 1977)		OSHA (OSHA, 1976)		NIOSH (1978)	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Epichlorohydrin	5	20	5	20	---	2 19 (15-minute ceiling)
Fluoride	---	2.5	---	2.5	---	2.5
Hydrochloric acid	5	7	---	---	---	---
Hydrofluoric Acid	3	2	3	---	≈6 ≈12 (15-minute ceiling, fluoride ion)	2.5 5.0 (15-minute ceiling, fluoride ion)
Iron oxide fumes	---	5	---	---	---	---
Lead, inorganic fumes and dusts	---	0.15	---	0.2	---	<0.1
Mercury, inorganic	---	0.05	---	0.1 (ceiling)	---	0.05
Nickel	---	0.1 (soluble compounds)	---	1 (inorganic and compounds)	---	0.015 (inorganic and compounds)
Nitric Acid	2	5	2	---	2	5
Perchloroethylene	100	670	---	---	---	---
Phosgene	0.10	0.4	0.1	---	0.1 0.2 (15-minute ceiling)	0.4 0.8 (15-minute ceiling)

Table 5. Threshold Limit Values, OSHA Promulgated Standards, and NIOSH Recommended Criteria* (Cont'd)

	TLV (ACGIH, 1977)		OSHA (OSHA, 1976)		NIOSH (1978)	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Phosphoric Acid	---	1	---	---	---	---
Platinum (soluble salts)	---	0.002	---	---	---	---
Rhodium						
fumes and dusts	---	0.1	---	---	---	---
soluble salts	---	0.001	---	---	---	---
Selenium Compounds	---	0.2	---	---	---	---
Silica, crystalline	---	---	---	10	---	0.050
Silicon	---	10	---		---	---
Silver metal and soluble compounds	---	0.01	---	---	---	---
Sodium Hydroxide (Caustic soda)	---	2	---	2	---	2 (15-minute ceiling)
Sulfuric Acid	---	1	---	1	---	1
Tellurium	---	0.1	---	---	---	---
Thallium, soluble compounds	---	0.1	---	---	---	---

Table 5. Threshold Limit Values, OSHA Promulgated Standards, and NIOSH Recommended Criteria* (Cont'd)

	TLV (ACGIH, 1977)		OSHA (OSHA, 1976)		NIOSH (1978)	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Tin, inorganic compounds except SnH_4 and SnO_2	---	2	---	---	---	---
1,1,1-Trichloroethane	350	1,900	350	---	350 (15-minute ceiling)	1,910 (15-minute ceiling)
Trichloroethylene	100	535	100 200 (acceptable ceiling) 300 (maximum ceiling, 5-minutes in any 2 hours)	---	25	134
Zinc oxide fume	---	5	---	5	---	5 15 (15-minute ceiling)

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ABSTRACT: This information profile on jewelry manufacturing (SIC-391) is part of a group of 46 such profiles that provide information about chemicals or industrial processes considered to be potential occupational hazards. Each profile contains summary data on known and suspected health effects, the extent of worker exposure and the industrial importance of either a single chemical, class of chemicals, or a particular industrial process. The report was developed for use by occupational safety and health professionals in industry, and labor and other areas, to provide them with a synopsis of information in their workplaces.

17. Document Analysis a. Descriptors

Toxicology
Physiological-effects
Chemical-properties
Physical-properties
Occupations
Industrial-processes
Work-environment
Safety-research

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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INTRODUCTION

An information profile is a working paper used by the National Institute for Occupational Safety and Health (NIOSH) to assist in establishing Institute priorities. It is an initial step in determining the need to develop comprehensive documents or to initiate research. Each profile summarizes data on known and suspected health effects, the extent of worker exposure, physical and chemical properties, and the industrial importance of individual chemicals and classes of chemicals. The profile may also be used by industry, labor, and the occupational health community as a synopsis of information on each subject and to identify possible health hazards associated with their workplaces.

Although detailed literature searches are conducted using computerized and manual searching techniques to identify pertinent and recent information, not all the literature obtained is incorporated in the report due to the summary nature of the profiles. Further, literature published after 1978 may not be included in these profiles because it was generally unavailable at the time the search was completed.