#1301 CHROMIUM

Public Citizen

NEWS RELEASE

HOLD FOR RELEASE UNTIL
Mon., July 19, 1993 10:00 a.m.

CONTACT: Andrew Silow Carroll
202/833-3000 x.203

CONSUMER GROUP, LABOR UNION SAY GOVERNMENT STANDARDS DON'T PROTECT WORKERS FROM CANCER-CAUSING CHROMIUM

WASHINGTON, D.C. -- The Public Citizen Health Research Group and the Oil, Chemical & Atomic Workers International Union (OCAW) today petitioned the Occupational Safety and Heath Administration (OSHA) for an Emergency Temporary Standard to lower the amount of exposure to chromium (VI) compounds in the workplace to 1/200th of current allowable levels.

The consumer group and labor union told a news conference that the current federal standards leave thousands of workers exposed to dangerous levels of the highly carcinogenic chemicals. The groups cited studies showing that chromium (VI) compounds, commonly used in many industrial processes, have the potential to cause lung cancer in up to 22 percent of workers who are exposed for a working lifetime to levels currently allowed by OSHA.

More than 200,000 workers are exposed to chromates every year, the groups estimate, including 1,000 OCAW members. These workers include pigment-makers, dyers, chrome platers, steel workers, painters, welders, printers and those manufacturing the compounds themselves.

The groups also revealed that work-site inspections conducted by OSHA between 1980 and 1992 indicate that 15 percent of the chromium (VI) readings exceeded the current permissible exposure level (PEL), and that 52 percent were double the maximum PEL called for in today's petition. The group provided examples of companies with dangerously high exposure rates in 14 states.

"Every day that OSHA delays lowering the standard, more and more workers are doomed to getting lung cancer," said Dr. Sidney M. Wolfe, M.D., Director of the Public Citizen Health Research Group. "The data make clear that current permissible exposure levels do not do enough to protect worker's health and must be changed."

Chromium exposure has been associated with lung cancer since 1890. The Environmental Protection Agency, the National Toxicology Program and the International Agency for Research on

(more)

Cancer have all classified chromium as a confirmed human carcinogen.

Currently, workers can legally be exposed to an average of 100 ug/m^3 (micrograms per cubic meter) of chromium over an eight-hour period. In 1975 and again in 1988, the National Institute for Occupational Safety and Health (NIOSH), a branch of the U.S. Department of Health and Human Services, suggested that the permissible exposure level to chromium should be 100 times less than the then existing standard, or 1 ug/m^3. OSHA declined to review the standard at that time, and has allowed the PEL to remain at 100 ug/m^3.

Public Citizen and the OCAW call for a PEL of 0.5 ug/m^3, or 200 times less than the current OSHA level. Among the evidence they cited were:

* Surveys of chromium (VI)-producing plants in the United States revealing rates of lung cancer 13 to 31 times the rate in the general population;

* Findings of increased rates of lung cancer among chromium workers in Britain, Japan, Germany and Norway;

* Several studies documenting the cancer-causing potential of chromium (VI) in animal models;

* Documentation of significantly increased chromosomal danger among chrome platers, and;

* Studies documenting other health hazards posed by exposure, including rashes, skin sores, perforations and sores of the nasal septum, worsening of asthma and allergic reactions.

"The evidence is overwhelming that there are serious health hazards posed by worker's exposure at the current legal level, yet OSHA has failed to act," said Robert E. Wages, President of the OCAW. "We call on OSHA to take action and prevent hundreds if not thousands of cases of lung cancer and other diseases among American workers."

# # #

Public Citizen is a nonprofit, consumer advocacy organization founded by Ralph Nader in 1971. The Public Citizen Health Research Group was co-founded by Nader and Dr. Sidney M. Wolfe in 1972.

The Oil, Chemical & Atomic Workers International Union (OCAW) represents 100,000 employees of petroleum, chemical, atomic and related industries.

CHROMIUM (VI) PETITION FACT SHEET

by
The Oil, Chemical & Atomic Workers International Union (OCAW)
and
Public Citizen's Health Research Group (PCHRG)

1) What is chromium (VI)? What are some chromium (VI) compounds?

- Chromium is an element that is ubiquitous in trace amounts in the rocks of the earth's crust. Chromium (VI) is one form of chromium. Other forms of chromium exist such as chromium (III) and chromium (V), however chromium (VI) is the form that poses the greatest health risk to exposed workers.
- Chromium (VI) compounds include agents such as chromic acid, an orange red crystalline compound used in chrome plating, potassium dichromate, a bright red crystalline substance which is used extensively in chemistry and industry, and lead chromate, a bright yellow substance which is used as a pigment.

2) What kinds of jobs involve chromium (VI) exposure? How many workers are exposed? How are workers exposed?

- Examples of workers exposed to chromium compounds include, those manufacturing chromium (VI) compounds, pigment-makers, dyers, chrome platers, steel workers, painters, welders, printers, and many others.
- In 1983, the National Occupational Exposure Survey estimated that 200,000 workers were exposed to chromium (VI).
- Workers can be exposed in a variety of ways including breathing in dust or fumes, splashing chromium (VI) containing compounds on the skin or into the eyes, or ingesting chromium (VI) containing compounds by accident.

3) What is the evidence that chromium (VI) causes lung cancer?

- Surveys of chromium (VI) producing plants in the USA have revealed rates of lung cancer that were 13-31 times the rate in the general population
- Increased duration of exposure to chromium (VI) has been associated with an increased risk of lung cancer
- Similar increased rates of lung cancer have been documented among chromium (VI) workers in Britain, Japan, Germany, and Norway
- Several studies have documented the cancer causing potential of chromium (VI) in animal models
- A significant increase in chromosomal damage has been documented in chrome platers. DNA damage is believed to be a key step in the development of cancer

4) **Why are the petitioners seeking an emergency reduction in the allowable exposure to 1/200th of what it is now? What is the role of OSHA?**

- Chromium (VI) compounds, commonly used in many industrial processes, have the potential to cause lung cancer in up to 22% of workers who are exposed to levels currently allowed by OSHA for a working lifetime. Currently the OSHA Permissible Exposure Level (PEL) is 100 ug/m^3.

- OSHA has the responsibility of assuring workers a safe work environment. OSHA could uphold this responsibility by:
  1) immediately adopting an emergency temporary standard providing for a maximum allowable chromium exposure of 0.5 ug/m^3 8 hour time-weighted average
  2) immediately scheduling a hearing in accordance with 30 U.S.C. 811(a)
  3) allowing the petitioners an opportunity to appear at the hearing referred to under #2, above

5) **What other health hazards are posed by exposure to chromium (VI)?**

- In addition to the increased risk of lung cancer, PCHRG and the OCAW point to other health hazards posed by exposure to chromium. These health hazards include rash, skin sores, perforations and sores of the nasal septum, worsening of asthma, and allergic reactions.

6) **What is the significance of the attached list of companies which were in violation of the current OSHA standard?**

- The list of companies is a summary of the national OSHA inspection data from 12/89 - 10/92. The entries in the table are listed alphabetically by state. The table provides a partial list of the corporations which were cited for violations of chromium (VI) exposure to workers.
- The list of companies illustrates the fact that many corporations throughout the country are allowing workers to be exposed to potentially toxic levels of chromium (VI).

7) **How can manufacturers reduce the risk of workplace exposure?**

- There are several actions which manufacturers can take to minimize worker exposure to chromium (VI). Examples of possible actions include using a substitute compound which is non-toxic, enclosing the manufacturing process, improving worksite ventilation, and providing protective equipment for exposed workers.

8) Who are the OCAW and PCHRG?

- The Oil, Chemical & Atomic Workers International Union (OCAW) is a labor union with approximately 100,000 members. An estimated 1000 OCAW members are exposed to chromium (VI) compounds.
- Public Citizen's Health Research Group (PCHRG) is a non-profit consumer advocacy group which focuses on health issues. PCHRG has a well established history of working to diminish worksite exposure to toxic substances. PCHRG has previously petitioned OSHA to set lower worksite PEL's for chloroform, radon, ethylene oxide, benzene, cadmium, environmental tobacco smoke, 4,4' methylene-bis(2-chloroanaline) - MOCA, and thirteen other compounds.

PERSONAL STATEMENT

Cecil Runk - Member
OCAW Local 4153, Corpus Christi, Texas

July 19, 1993

Workers in the plant are exposed to hexavalent chromium while doing routine operations functions. Pump seals and pipe flanges are a constant source of leaks spraying a mist or drying to a dust and becoming airborne. Storage tanks often overfill and overflow onto the floor causing a turbulent airborne mist. These tanks are not sealed or vented to a scrubber. They are opened and the contents measured daily, exposing workers to a steamy mist. Filters used to leach clean chromium liquor from mud slurry are open to the atmosphere, are old, worn, and leak, exposing workers to mist and contaminated liquor and slurry.

Much of the equipment installed to satisfy air quality regulations concerning stack emissions seems to be engineered and installed hastily without much concern for worker exposure when operating and cleaning components. Filter bags and cartridges are very contaminated and usually contaminate workers when they are removed for cleaning.

These are a few examples of worker exposure in the plant. The company has a "dry floors" policy in place that is supposed to keep exposure to a minimum. It has enjoyed a limited success, but is hampered by a lack of maintenance.

The company provides equipment to protect employees from exposure; respirators, rubber gloves, rubber boots, coveralls, eye goggles, hard hat, ear plugs, etc. The company, also provides showers and washes all work clothes.

The company monitors exposure with personnel and area samplers. These samplers have in some cases resulted in stricter rules concerning the use of respirators to diminish personal exposure, but have not resulted in much progress in the way of cleaning up the source.

In conclusion, I would like to ask OSHA on behalf of myself and my fellow workers to immediately set an emergency temporary standard for chromium exposure that protects the health of all workers.

TWENTY COMPANIES INSPECTED BETWEEN 1989-1992 AND FOUND IN VIOLATION OF THE OSHA CHROMIUM (VI) STANDARD

Table 1 is a summary of the national OSHA inspection data from 12/89 - 10/92. The entries in the table are listed alphabetically by state. The table provides a partial list of the corporations which were cited for violations of chromium (VI) exposure to workers.

The table is constructed as follows:

- JOB - job title listed on the OSHA data report
- COMPANY - site inspected
- SEVERITY
  - The severity is calculated by taking the measured value and dividing by the standard for chromium (100 ug/m^3). The severity is thus how many times higher than the exiting standard the worker's exposure was. For example, the spray painter from Industrial Metal Fabricator in Wayne, New Jersey was exposed to an eight hour time weighted average (TWA) chromate concentration of 3.40 x the current standard of 100 ug/m^3, or 340 ug/m^3. This is 680 times higher than the 0.5 ug/m^3 standard sought in our petition.
  - The severity measure is listed as a ceiling (C), an eight hour time weighted average (TWA), or a short term exposure level (stel).
- DATE - the first day on which monitoring was begun

The table illustrates the fact that workers in a variety of occupations continue to be exposed to extremely dangerous levels of chromium (VI).

COMPANY	JOB	SEVERITY	DATE
Boaz Lowded International 35 Industry Dr Hwy 205 Boaz, AL	Painter	7.10 (C) 4.10 (TWA)	3/26/92

COMPANY	JOB	SEVERITY	DATE
Hydraulics International 9035 Independence Ave. Los Angeles, CA	Painter	1.70 (TWA)	7/25/91
Cypress Aviation Co. 3636 Drainfield Rd. Lakeland, FL	Spray Painter	10.00 (C)	10/2/89
Diversified Services Inc. 28 Clark - Industrial Ave. Wellington, KS	Process Supp.	1.50 (C)	12/13/90
Mineral Pigments Inc. 711 Muirkirk Rd. Beltsville, MD	Operator	4.90 (C) 1.3 (TWA	10/3/91
American Iron Works Inc. 3201 Kenilworth Ave. Bladensburg, MD	Spray Painter	4.80 (TWA)	11/8/91
New England Tap Fox Hill Industrial Park Foxboro, MA	Plater	1.70 (C)	11/19/90

COMPANY	JOB	SEVERITY	DATE
Zero Corp. 288 Main St. Monson, MA	Mill-Spec Spray Painter	93.50 (C) 1.19-2.60 (C)	10/4/91
Ring Finishing Inc. 6431 E. Palmer Detroit, MI	Plater Packer	1.40 (stel) 1.20 (stel)	5/13/91
Falstrom Co. Falstrom Ct. Passaic, NJ	Sander/Help	4.5 (C)	12/10/90
Industrial Metal Fabricators 90 Newark-Pompton Trpk Wayne, NJ	Spray Painter	90.0 (C) 3.40 (TWA)	12/11/89
Highway Department 3235 Chili Ave. Chili Center, NY	Machine Oper.	44.00 (TWA) 18.00 (TWA)	4/10/90
Barium and Chemicals Inc. County Rd. 44 Steubenville, OH	Laborer	45.00 (C)	2/22/90
Norris O'Bannon Div. of Dove 4615 S. 49th W. Ave. Tulsa, OK	Plater	3.70 (C)	11/06/91

COMPANY	JOB	SEVERITY	DATE
Kovatch Corp. 500 W. Catawissa St. Nesquehoning, PA		2.20 (TWA) 9.60 (C)	1/4/91
Coast Materials Inc. 259 E. Goodnight Aransas Pass, TX	Paint & Bodyman	4.10 (C)	2/4/91
General Dynamics N. General Dynamic Blvd Fort Worth, TX	Painter Fin. Paint. Chem Tank Chrg Monorail Mech. Chem Tank Chrg Painter(2) Assembler	1.90 (C) 5.50 (C) 6.10 (C) 1.50 (C) 50.00 (C) 8.80 (C) 5.70 (C) 3.00 (C)	9/18/90
Carolina Color Corp. 913 E. Pleasant Run Lancaster, TX	Bending	7.60 (C)	3/30/91
Wayne Pigment Corp. 300 S. Barclay Milwaukee, WI	Bag Filler(2)	1.58 (C) 2.18 (C)	2/28/92
Jackson Lumber Harvester Inc. Hwy 37 N. Mondovi, WI	Paint. Fabric.	56.00 (C)	5/7/91

TABLE 1 Compiled from the national OSHA site inspection data. List alphabetized by state.

Petition Requesting a Reduced Tolerance for Chromium (VI) (Hexavalent Chromium) through an Emergency Temporary Standard Issued under the Authority of the Occupational Safety and Health Act

July 19, 1993

Petitioners

Public Citizen's Health Research Group
and the
Oil, Chemical, & Atomic Workers International Union

Table of Contents

Public Citizen's Health Research Group Oil, Chemical & Atomic Workers International Union Petitioners	))))))))	July 19, 1993

TO: Honorable David Zeigler
Acting Assistant Secretary for Occupational Safety and Health

PETITION REQUESTING A REDUCED TOLERANCE FOR HEXAVALENT CHROMIUM THROUGH AN EMERGENCY TEMPORARY STANDARD ISSUED UNDER THE AUTHORITY OF THE OCCUPATIONAL SAFETY AND HEALTH ACT.

CITIZEN PETITION

Petitioners request the Acting Assistant Secretary for Occupational Safety and Health to exercise his authority under section 6(c) of the Occupational Safety and Health Act, 29 U.S.C. Section 655(c) to amend C.F.R. Part 1910 (Table Z) by promulgating an emergency temporary standard lowering allowable exposure to hexavalent chromium from the present allowable eight hour time weighted average of 100 ug/m^3 (micrograms per cubic meter) to an eight hour time weighted average of 0.5 ug/m^3.[1] The grounds for the requested emergency temporary standard are that (1) exposure to hexavalent chromium presents a grave danger of lung cancer to employees, and (2) the requested emergency temporary standard is necessary to protect workers from these grave health risks.

I. PETITIONERS

Petitioner Public Citizen's Health Research Group is a Washington-based non-profit organization engaged in public interest research and advocacy on health issues, including occupational health.

Petitioner Oil, Chemical & Atomic Workers International Union (OCAW) is a labor union with its principal headquarters in Lakewood, CO. The OCAW represents at least 1000 workers who are potentially exposed to hexavalent chromium.

II. AUTHORITY FOR PETITION

Petitioners submit this petition pursuant to sections 6(b) and 6(c) of the Occupational Safety and Health Act of 1970, 29 U.S.C. § 655(b) and (c), as well as 29 C.F.R. § 51911.3.

III. EVIDENCE OF GRAVE DANGER FROM OCCUPATIONAL EXPOSURE TO HEXAVALENT CHROMIUM.

INTRODUCTION

Since the eighteenth century, chromium has been used in a wide range of alloys, chemical processes and finished products in the United States. Although chromite ore has not been mined in the USA since 1961, imported ore and ferrochromium are used extensively in industrial processes. In 1990, the USA imported 565 thousand tons of chromite ore and 2.7 million tons of ferrochromium.[2] A schematic diagram of the processing of chromium ore and potential occupation exposure is presented in Figure 1. Quantitatively, the most important use of chromium is to make metal alloys.[3] In 1988, the USA produced close to 2 million tons of stainless steel.[4] Chromite ore is also reduced to sodium chromate and chromic acid, which is used in chrome plating. A variety of chromates are used in the production of pigments. Because of its unique chemical properties, chromium is also used as a catalyst in a variety of chemical processes and as a component of the cement used to make refractory bricks.[5]

A significant number of workers are exposed to chromium. In 1977, the National Institute of Occupational Safety and Health estimated that 2 million workers were exposed to chromium and chromium containing compounds (Table 1).[6] In 1981, Centaur Associates estimated that 1 million workers are exposed to chromium.[7] Of these workers, approximately 390,000 had exposure to the hexavalent form of chromium (chromium (VI)). Many of these workers had exposures exceeding the current OSHA Permissible Exposure Limit for chromium (VI). In 1983, the National Occupational Exposure Survey estimated that 200,000 workers are exposed to hexavalent chromium.[8]

Further evidence of excessive worker exposures to chromium can be obtained by examining OSHA records of personal monitoring inspections of the workplace.[9] Between January 1, 1980 and October 31, 1992, OSHA inspectors took 2163 personal sampling measurements for exposure to chromium. This data does not include inspections by states with 18(b) programs prior to 1982, nor were results from California, Michigan, or Washington included in this data set. Of these 2163 samples, 328 (15 percent) exceeded the current PEL (100 ug/m^3). In addition, 1142 of the 2163 samples (52 percent) had exposures greater than or equal to 1 ug/m^3 (twice the proposed Emergency Temporary Standard).

Chromium is also released into the atmosphere as a contaminant of industrial processes. For instance, chromium is found in trace amounts in coal, oil and cigarettes, and it is released when these products are burned. It is estimated that more than 5000 metric tons of chromium are released into the air each year.[3]

HEALTH EFFECTS

Human Epidemiology Studies

Chromium was known to be carcinogenic prior to this century. The first case of chromium-induced lung cancer was reported in 1890, over 100 years ago.[10] As early as the 1930's, the German government declared chromium to be carcinogenic and lung cancer a compensable disease.[11] More recently, the Environmental Protection Agency, the National Toxicology Program, and the International Agency for Research on Cancer have designated chromium a confirmed human carcinogen.[3,4,12]

Lung Cancer in Chromium Production Plant Workers

In the late 1940's and early 50's, two surveys of the seven chromium producing plants in the USA[13,14] showed rates of lung cancer that were 13 to 31 times the rate in the general population. The risk of cancer reported in these studies may have understated the true lung cancer risk, since the authors identified lung cancer only in workers who were currently employed at the plant. Workers who retired or changed jobs were not counted in these studies, although they were still at risk of developing cancer.

One of these plants (Painesville, Ohio) was also studied separately by Mancuso et al.[15] This study documented an increased proportion of deaths due to respiratory cancer in 332 workers who were first employed between 1931 and 1937 and followed until 1947. Based on industrial hygiene surveys, it was estimated that this cohort of workers were exposed to chromium at a time weighted average concentration of 110 to 660 ug/m^3. Person-years of exposure ranged from 220 to 6110 ug/m^3-year. Since the analytical techniques could not distinguished chromium (VI) from chromium (III), these measurements were for total chromium. This study suggests that there may be an increased risk of cancer in workers exposed to as little as 110 ug/m^3 of chromium.

Follow-up studies were conducted in three of the original seven plants (located in Jersey City, NJ, Painesville, Ohio, and Baltimore, MD).[16,17] In one of these studies, all employees who worked at these plants were included in the study. Deaths were identified using Old Age and Survivors Disability Insurance records and death certificates. Of the 1212 workers included, 71 developed respiratory cancer, which was approximately nine times the rate in the general population. In addition, increasing duration of exposure was associated with increased risk of lung cancer, suggesting that increasing exposure to chromium increased the risk of developing lung cancer.

Hayes et al.[18] examined mortality of workers employed at a chromate production plant in Baltimore between 1945 and 1977. The study population was divided according to those hired before and after new ventilation systems were installed. An elevated risk of lung cancer was observed in workers who were exposed to high concentrations of chromium as well as workers who were long-term employees. Workers hired after new ventilation was installed had a similar incidence of respiratory cancer to those hired earlier (4.0 for long term workers hired after the new ventilation vs 3.0 workers for long term workers hired before the new ventilation system), although the increase was not statistically significant due to the small numbers of workers exposed. Braver et al.[19] estimated worker exposure to chromium in the old plant to be between 218 and 413 ug/m^3, while exposure in the new plant was between 12 and 120 ug/m^3.

Similar epidemiologic studies have shown a substantially elevated risk of lung cancer in workers in the chromate production industry in England[20,21] and Japan.[22] The incidence of lung cancer increased with the duration of exposure. The risk was still elevated, although the small number of workers exposed make it impossible to reach statistical significance.

Lung Cancer in Chromate Pigment Industry Workers

Elevated risks of respiratory cancer have also been observed in the chromate pigment industry. An increased risk of lung cancer of 1.6 to 44 times the general population has been observed among workers in chromate pigment industries in the USA[23], Norway[24], the UK[25], and Germany.[26] In 1989, Hayes et al.[27] examined 1879 workers employed in a New Jersey plant which produced zinc and lead chromate based pigments. The workers had been employed for at least one month between 1940 and 1969 and were followed through 1982. The risk of lung cancer increased with duration of employment, reaching three times the general population rate in employees with greater than ten years on the job.

Lung Cancer in Chromium Plating Industry Workers

Exposure to chromium in the chrome plating industry is also associated with increased risk of cancer in Italy[28], UK[29], and the US.[30,31] Franchini[28] reported on 178 workers who had worked at plating between 1951 and 1981. The incidence of lung cancer in this small group of workers was approximately 3 times the general population and increased with increasing duration of employment and intensity of exposure. Sorahan[29] examined the mortality of 2689 chrome platers who were employed in the UK between 1946 and 1975 and followed until 1983. The incidence of lung cancer in exposed workers was significantly increased (1.6 times the general population). These workers were also exposed to nickel, however no increase in cancer risk was associated with nickel exposure. It was concluded that the cancers seen in the workers with mixed exposures were due to chromium.

In the US, Silverstein et al.[32] studied mortality in workers in a Midwestern die casting and electroplating plant. They found the percentage of deaths due to lung cancer was two to four times the population average. These employees were also exposed to nickel and aromatic hydrocarbons. A nested case referent study suggested that risk of cancer was greatest in departments with exposure to chromium. Although this type of proportional mortality study is not generally used for establishing causation, the results from the case control analysis of the same group of workers support the hypothesis that exposure to chromium results in an increased risk of cancer.

Possible Influence of Smoking on Cancer in Chromium Workers

Cigarette smoking is a well established cause of lung cancer[33] which needs to be considered in evaluating epidemiological studies on cancer. None of the epidemiology studies discussed in this petition specifically controlled for the worker's smoking habits. There is the potential that differences in smoking habits of chromium exposed workers and the general population may account for some of the increased mortality observed in chromium exposed workers. However, differences in smoking habits can not account for all of the increased risks of cancer observed in chromium exposed workers. Based on a study of smoking prevalence in the United States, Levin et al. estimated that increased risk of lung cancer due to smoking in ore refining and foundry workers would be about 10 percent, whereas chemical workers would have 30 percent <u>less</u> risk of cancer, due to the lower prevalence of smoking in this occupational group.[34] A comparison of blue collar and white collar smoking prevalence suggests that the magnitude of the difference in lung cancer risk due to differences in smoking pattern to be about 10 percent.[35] Since the excess lung cancer risks observed in the epidemiological studies were considerably greater than 10 percent, smoking alone can not account for the increased risk of cancer in chromium exposed workers.

Summary

Workers exposed to chromium in chromate production, chromate pigment production, and chrome plating are at increased risk of developing cancer of the respiratory tract. Increasing the duration or intensity of exposure increased the risk of developing lung cancer. Based on these results, the EPA, the National Toxicology Program, and the International Agency for Research on Cancer have designated chromium a confirmed human carcinogen.[3,4,12]

<u>Non Cancer Toxicity in Humans</u>

In addition to its carcinogenic properties, chromium can cause other forms of toxicity in exposed workers. For instance, chromium can cause nasal septum perforations.[36] In one study, electroplating workers exposed to up to 49 ug/m^3 total chromium (9 ug/m^3 hexavalent chromium, much less than the current allowable limit) had increased perforations or ulcerations of the nasal septum.[37] In addition, chromium exposure can result in decreased pulmonary function as indicated by reduced pulmonary function tests in exposed workers. These findings are indicative of obstructive lung disease.[38,39]

Exposure to chromium via inhalation or dermal exposure can result in the development of a hypersensitivity reaction.[40] Dermal exposure is associated with a delayed contact dermatitis.[41,42] Chromium eczema is one of the most frequently encountered occupational dermatoses.[43] Chromium inhalation is associated with an asthmatic reaction in sensitive individuals.[44]

Experimental Carcinogenicity Studies

Carcinogenicity studies in experimental animals support the causal relationship between workplace exposure to chromium and the development of cancer in workers. Several studies have demonstrated the carcinogenicity of hexavalent chromium. For instance, calcium chromate has induced cancer via intramuscular[45], intraperitoneal[46], intrabronchial[47] and intratracheal administration.[48] The carcinogenicity of these compounds is best documented for the slightly soluble chromium compounds, such as zinc and strontium chromate.[47,49] Soluble chromium compounds, such as sodium dichromate, are also carcinogenic via intratracheal administration.[48] Zinc yellow is carcinogenic via intrapleural administration.[45] Sodium dichromate also produced a non-significant increase in tumor incidence via inhalation exposure, which may have been due to the small number of treated animals in the study.[50]

Chromium (III) compounds have not been studied as thoroughly as the chromium (VI) compounds. The studies which have been conducted on these have suffered from certain limitations. It is generally agreed that chromium (III) compounds have been inadequately evaluated for carcinogenic potential.[4,12]

Experimental Mutagenicity Studies

Mutagenicity (DNA damage) is a useful biological indicator of the cancer-causing potential of a chemical substance. Since many carcinogens cause cancer by damaging DNA, positive results in mutagenicity assays provide supporting evidence of the carcinogenicity of a substance. These assays can also provide insights on the mechanisms of toxicity.

Results from in vitro mutagenicity tests support the carcinogenicity of chromium. A summary of 669 assays on various chromium compounds (chromium (0), chromium (II), chromium (III), and chromium (VI)) has been performed.[51] Soluble and highly soluble chromium (VI) compounds (potassium chromate, sodium dichromate, ammonium dichromate, potassium dichromate, ammonium chromate, chromium trioxide, calcium chromate, strontium chromate and basic zinc chromate) are mutagenic in a number of test systems. For instance, potassium chromate induces mutations in bacteria[52] and cultured mammalian cells[53], damages DNA as indicated by unscheduled DNA synthesis in Chinese hamster ovary cells[54], causes chromosomal aberrations in vivo[55] and in vitro[56], and transforms cells.[57] In contrast, poorly soluble chromium (VI) compounds (zinc chromate, chromium orange, molybdenum orange, barium chromate, chromium yellow, and lead chromate) were less mutagenic, unless they were first solubilized in acid or base solutions. This suggests that the substances need to be in a soluble form to cross the cell membrane to damage DNA. Tests evaluating soluble chromium (III) (chromic chloride, chromic acetate, chromic nitrate, chromic sulfate, and chromic potassium sulfate, basic chromic sulfate, chromium alum, chromic phosphate) were generally negative in cellular and in vivo systems. Chromium (III) does damage DNA in acellular systems, suggesting that soluble chromium (III) is incapable of crossing the cell membrane. In contrast, poorly soluble and insoluble chromium (III) compounds (chromic hydroxide, chromic oxide, cupric chromite) have caused sister chromatid exchange in Chinese hamster ovary cells[52,58], suggesting that they have the potential to be taken up by pinocytosis (the process of ingestion of a particle by a cell) and release chromium (III) intracellularly in vitro. Relatively few studies have been conducted on insoluble or poorly soluble chromium (III) compounds. These substances are negative in bacterial systems. Metallic chromium and chromium (II) do not appear to be mutagenic.

In summary, numerous test results support the mutagenicity of chromium (VI). In cases in which chromium (VI) was negative, the compounds tested were relatively insoluble and presumably could not cross the cell membrane to affect the DNA. In contrast, soluble chromium (III) is generally negative in mutagenicity tests, except when acellular tests were used. When soluble chromium (III) was positive, the chromium (III) was generally contaminated by chromium

(VI) or much higher concentrations were required to induce mutations than would be the case with chromium (VI). This suggests the permeability of the cell membrane to soluble chromium (III) is less than its permeability to chromium (VI). Thus, soluble chromium (III) is not generally mutagenic. In contrast, there is suggestive evidence the insoluble or poorly soluble chromium (III) compounds may be mutagenic in mammalian cell culture, possibly due to chromium uptake via pinocytosis. More research is required on the mutagenicity of insoluble and slightly soluble chromium (III) compounds. Since these studies demonstrate the mutagenicity of chromium (VI), these results support the carcinogenicity of chromium (VI). In contrast, chromium (III) compounds appear to have less carcinogenic potential.

Evidence of the Genotoxicity of Chromium in Workers

In addition to being mutagenic in in vitro and in vivo experimental models, chromium causes chromosomal damage in exposed workers. A significant increase in the incidence of sister chromatid exchange has been observed in chromium platers.[56,59] This increase in sister chromatid exchange has been observed in workers exposed to chromium at air concentrations as low as 8 to 27 ug/m^3.[60] These studies suggest that chromium can affect DNA integrity in exposed workers, even at concentrations below the current OSHA Permissible Exposure Limit. Since DNA damage is believed to be a key step in carcinogenesis, this demonstrates that workers may be at increased risk of developing cancer when exposed at the Permissible Exposure Limit.

Influence of Valance on the Toxicity of Chromium

The difference in the toxicities of chromium (III) and chromium (VI) is due to the ability of chromium (VI) to penetrate the cell membrane. Soluble chromium (VI) is taken up by cells 1000 times more efficiently than chromium (III).[61] Once inside mammalian cells chromium (VI) is reduced to chromium (III) by local enzymes.[62] Chromium (III) can directly damage DNA.[63] Chromium (VI) can be reduced, and thereby inactivated, by a variety of body constituents.[64] The toxicity of chromium (VI) is, therefore, most prominent at sites of direct contact such as the skin and respiratory tract. Chromium is relatively non-toxic following oral exposure.[65,66]

IV. REGULATORY HISTORY

The National Institute of Occupational Safety and Health (NIOSH) published and forwarded to OSHA an extensively documented Criteria Document on Chromium in 1975.[11] In this review, they made a distinction between the slightly soluble chromates, which they felt were carcinogenic, and the more soluble chromates, which they felt had not been proved to be carcinogenic at that time. For the carcinogenic chromates they said that the level in the air should be kept as low as possible, but for technical reasons the lowest levels that could be accurately monitored were equivalent to a time weighted average (TWA) of 1 ug/m^3 (0.001 mg/m^3) as chromium (VI).

In 1988, the representatives of NIOSH testifying at OSHA's informal hearings on the Air Contaminants Standard[67] declared that new scientific evidence suggested that all hexavalent chromium compounds should be considered as potential occupational carcinogens for regulatory purposes. Citing positive epidemiology and experimental carcinogenicity studies, they urged OSHA to adopt the most protective of the available standards for hexavalent chromium compounds, which at the time was 1 ug/m^3 set by NIOSH. In the Air Contaminants Standard, OSHA stated that hexavalent chromium is carcinogenic, but placed the issuance of a lower PEL on hold due to the complexity of the issues involved.[68] Currently, the OSHA PEL is 100 ug/m^3.[69] The American Conference of Governmental Industrial Hygienists has issued a Threshold Limit Value of 50 ug/m^3.

V. ASSESSMENT OF THE MAGNITUDE OF CANCER RISK TO CHROMIUM WORKERS

To assess the risk of cancer for workers exposed to chromium, it is necessary to quantitatively estimate the relationship between exposure to chromium and cancer risk. It is assumed that any exposure to chromium results in a finite risk of cancer. The relationship between exposure and cancer risk is expressed by:

$$P(d) = 1 - e^{(-B \times d)}$$

In which:

d = dose

P(d) = Risk of cancer at dose d

B = cancer potency factor, and

e = the base of natural logarithm (2.718...)

At low risks of cancer, this expression simplifies to:

$$P(d) = B \times d$$

Based on the analysis of epidemiology studies of workers exposed to chromium, the EPA has estimated the cancer potency factor for chromium to be 1.2×10^{-2} $(ug/m^3)^{-1}$ for human respiratory cancer due to environmental exposure to hexavalent chromium.[3] This cancer potency factor was derived from a study by Mancuso.[70] In addition, other estimates of the chromium cancer potency factor were made using epidemiology data from Langard et al.,[71] Axelsson et al.,[72] and Pokrovskaya et al.[73] The best estimate values of these analyses were within an order of magnitude (factor of 10), suggesting confidence in the calculated cancer potency factor due to the consistency in the estimated cancer risk factor across the four studies. Based on this value, a risk estimate for occupational chromium exposure can be calculated by applying the EPA methodology and substituting relevant values for workers.

To estimate excess lung cancer risk at the current OSHA PEL (100 ug/m^3), it is necessary to calculate the total dose which a worker receives over a working lifetime due to occupational exposure and to convert this value to a lifetime average daily exposure. Obviously, as absorption may vary considerably between workers, this in fact is a very <u>conservative</u> estimate. For this analysis, it is assumed that:

- the dose of chromium delivered to the surface of the lung is directly proportional to the concentration of chromium in the air and the worker's inhalation rate;
- the worker is exposed to the current Permissible Exposure Level for chromium (100 ug/m^3) for 8 hours/day;
- the worker does not use personal protective equipment;
- the worker breathes 20 m^3/day
- the worker breathes 10 m^3/day at the workplace
- the worker is exposed for 240 days/year
- the worker is exposed for 45 years; and
- the lifetime is 70 years.

Using these assumptions, the lifetime average daily exposure for a PEL of 100 ug/m^3 would be:

$$100\ ug/m^3 \times \frac{10\ m^3/day}{20\ m^3/day} \times \frac{240\ workdays/year}{365\ days/year} \times \frac{45\ years}{70\ years} = 21\ ug/m^3$$

Thus, the lifetime average daily exposure is 21 ug/m^3. Starting with the EPA's cancer potency factor of 1.2 x 10^{-2} (ug/m^3)$^{-1}$ the risk of lung cancer resulting from continuous <u>workplace</u> exposure to 100 ug/m^3 -- the current OSHA limit -- can be calculated:

$$\begin{aligned} P(d) &= 1 - e^{(-B \times d)} \\ &= 1 - e^{(-1.2 \times 10^{-2}\ (ug/m^3)^{-1} \times 21\ ug/m^3)} \\ &= 0.22\ or\ 22\% \end{aligned}$$

where 0.22 is the lifetime risk of cancer (P(d)) due to occupational exposure to 100 ug/m^3. **Put another way, 220 out of 1000 workers (22%) exposed to legal levels of chromium over a working lifetime of 45 years would be expected to contract lung cancer.**

The magnitude of the cancer risk posed by chromium is far in excess (220 times higher) of what the Supreme Court considers to be a significant risk. In the Benzene case, the Court stated that:

> ... if the odds are <u>one in a thousand</u> that regular inhalation of gasoline vapors that are two percent benzene will be fatal, a reasonable person might well consider the risk significant and take appropriate steps to decrease or eliminate it.[74] (emphasis added)

Using this as a guideline, there can be no doubt that workers face grave danger from chromium exposure.

More pertinently, the risk for lung cancer due to chromium exposure is similar to the cancer risk calculated by OSHA for workers exposed to ethylene oxide (April 21, 1983; 48 FR 17284) and arsenic (Jan 14 1983; 48 FR 1864, 1986) at the previous Permissible Exposure Limits for these substances. OSHA estimated the risk of cancer due to these compounds to be between 63 and 109/1000 for ethylene oxide and 148 to 425 for arsenic. On the basis of these cancer risks, OSHA acted to reduce the Permissible Exposure Limit for these compounds. For occupational exposure to chromium, the risk to workers is similar, and hence OSHA has a similar duty to act.

The workplace exposure associated with a lung cancer risk of 1 in one thousand can be calculated based on the equations presented above. Since the product B x d is small (as is the case with a cancer risk of 0.001), P(d) can be approximated by B x d. Thus, if the risk of cancer is represented by P(d) = B x d, then the dose (d) associated with a given risk of cancer is represented by d = P(d)/B. The lifetime average daily exposure associated with a 1 in 1000 risk of cancer is thus $0.001/(1.2 \times 10^{-2}\ (ug/m^3)^{-1})$, or 0.08 ug/m^3 for continuous lifetime exposure. This value is equivalent to a 45 year occupational exposure of 0.38 ug/m^3 for chromium. Given these data, we urge OSHA to adopt a Permissible Exposure Limit of no more than 0.5 ug/m^3 time-weighted average.

VI. RELIEF REQUESTED

Because of the grave danger resulting from exposure to chromium:

1) The petitioners request that the Assistant Secretary immediately adopt an emergency temporary standard providing for a maximum allowable chromium exposure of 0.5 ug/m^3 8 hour time-weighted average.

2) Pursuant to the request for an emergency temporary standard, the Petitioners request that the Assistant Secretary immediately schedule a hearing in accordance with 30 U.S.C. 811(a).

3) Petitioners request an opportunity to appear at the hearing referred to under #2, above.

VII. PRAYER FOR RELIEF

For the reasons set out, the petitioners request that the Assistant Secretary of Labor grant the relief set forth in this petition.

1. OSHA, Letter of interpretation, August 30, 1982, The letter states that, "The last two entries in table Z-2 'mercury' and 'chromic acid and chromates,' should be considered as 8-hour TWA standards and not ceiling standards." The letter lists the standard as 100 ug/m^3.

2. US Department of Commerce, Bureau of Census. *US Imports for Consumption and General Imports*, 1990.

3. US Environmental Protection Agency. Health Assessment Document form Chromium 1984 (US EPA-600/8-83-014), Research Triangle Park, NC, Environ Criteria and Assess Office.

4. IARC (International Agency for Research on Cancer) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Chromium, Nickel and Welding. 1990; 49:49-256. Lyons, France: World Health Organization.

5. Stern RM. Chromium compounds: production and occupational exposure. In: Biological and Environmental Aspects of Chromium. 1982 ed, Langard S. Amsterdam Holland, Biomedical Press pp. 5-48.

6. National Institute for Occupational Health and Safety. National Occupational Hazard Survey 1973-74, 1977. Cincinnati, Ohio.

7. Centaur Associates, Inc: Technological and Economic Analysis of Regulating Occupational Exposure to Chromium. Unpublished report prepared for OSHA, 1981.

8. NIOSH. National Occupational Exposure Survey (1980-83). Cincinnati, OH: DHHS 1984.

9. U.S. OSHA. National Sampling Activity by Substance/SIC for Chromic Acid & Chromates (as CrO3) (0686), Lead Chromate (0687), and Zinc Chromate (2612). December 21, 1992.

10. Langard S. One hundred years of chromium and cancer: a review of epidemiological evidence and selected case reports. Am J Ind Med 1990; 17:189-215.

11. National Institute for Occupational Health and Safety. Criteria for a recommended standard... Occupational Exposure to Chromium(VI). 1975. Cincinnati, Ohio. HEW Pub (NIOSH) 76-129.

12. US Department Health and Human Services. Sixth Annual Report of Carcinogens. 1991, NTP 85-002. pp 48-53.

13. Machle W, Gregorius F. Cancer of the Respiratory System in the United States Chromate-producing Industry. Public Health Rep 1948; 63:1114-1127.

14. Brinton HP, Frasier ES, Koven AL. Morbidity and mortality experience among chromate workers. Public Health Reports 1952; 67;835-847.

15. Mancuso TF, Hueper WC. Occupational cancer and other health hazards in a chromate plant: A medical appraisal I. Lung cancers in chromate workers. Ind Med Surg 1951; 20:358-363.

16. Taylor FH. The relationship of mortality and duration of employment as reflected by a cohort of chromate workers. Am J Public Health 1966; 56:218-229.

17. Enterline PE. Respiratory cancer among chromate workers. J Occup Med 1974; 16:523-526.

18. Hayes RB, Lilienfeld AM, Snell LM. Mortality in chromium chemical production workers:a prospective study. Int J Epidem 1979; 8:365-374.

19. Braver ER, Infante P, Chu K. An analysis of lung cancer risk from exposure to hexavalent chromium. Teratogen Carcinogen Mutagen 1985; 5:365-378.

20. Bidstrup PL, Case RAM. Carcinoma of the lung in workmen in the bichromate-producing industry in Great Britain. Br J Indust Med 1956; 13:260-264.

21. Alderson MR, Rattan NS, Bidstrup L. Health of workmen in the chromate-producing industry in Britain. Br J Indust Med 1981; 38:117-124.

22. Satoh K, Fukuda Y, Torii K, Eng M, Katsuno N. Epidemiological study of workers engaged in the manufacture of chromium compounds. J Occ Med 1981; 23:835-838.

23. Sheffet A, Thind I, Louria DB. Cancer mortality in a pigment plant utilizing lead and zinc chromates. Arch Environ Health 1982; 37:44-52.

24. Langard S, Vigander T. Occurrence of lung cancer in workers producing chromium pigments. Br J Indust Med 1983; 40:71-74.

25. Davies JM. Lung cancer mortality among workers making lead chromate and zinc chromate pigments at three English factories. Br J Indust Med 1984; 41:158-169.

26. Frentzel-Beyme R. Lung cancer mortality of workers employed in chromate pigment factories. J Cancer Res Clin Oncol 1983; 105:183-188.

27. Hayes RB, Sheffet A, Spirtas R. Cancer mortality among a cohort of chromium pigment workers. Am J Indust Med 1989; 16:127-133.

28. Franchini I, Magnani F, Mutti A. Mortality experience among chromeplating workers. Scand J Work Environ Health 1983; 9:247-252.

29. Sorahan T, Burges DC, Waterhouse JAH. A mortality study of nickel/chromium platers. Br J Ind Med 1987; 44:250-258.

30. Royale H. Toxicity of chromic acid in the chromium plating industry (1). Environ Res 1975; 10:39-53.

31. Silverstein M, Mirer F, Kotelchuck D, Silverstein B, Bennett M. Mortality among workers in a die-casting and electroplating plant. Scand J Work Environ Health 1981; 7(Suppl 4):156-165.

32. Silverstein M, Mirer F, Kotelchuck D, Silverstein B, Bennett M. Mortality among workers in a die-casting and electroplating plant. Scand J Work Environ Health 1981; 7:156-165.

33. US Department of Health and Human Services. Office of Smoking and Health. The Health Consequences of Smoking: Cancer. 1982.

34. Levin LI, Silverman DT, Hartge P, Fears TR, Hoover RN. Smoking patterns by occupation and duration of employment. Am J Indust Med 1990; 17:711-725.

35. US Department of Health and Human Services. Office of Smoking and Health. The Health Consequences of Smoking: Cancer and Chronic Lung Disease in the Workplace. 1985; pp 114-131.

36. Sanz P, Moline JL, Sole D, Corbella J. Nasal septum perforation in chromate-producing industry in Spain. J Occ Med 1989; 31:1013-1014.

37. Cohen SR, David DM, Kramkowski RS. Clinical manifestations of chromic acid toxicity: nasal lesions in electroplate workers. Cutis 1974; 13:558-568.

38. Bovet P, Lob M, Grandjean M. Spirometric alterations in workers in the chromium electroplating industry. Int Arch Occup Environ Health 1977; 40:25-32.

39. Lindberg E, Hedenstierna G. Chrome plating: Symptoms, findings in the upper airways, and effects on lung function. Arch Environ Health 1983; 38:367-374.

40. Decaestecker AM, Marez, T, Jdaini J, Frimat P, Hildebrand HF. Hypersensitivity to dichromate among asymptomatic workers in a chromate pigment factory. Contact Dermatitis 1990; 23:52-53.

41. Newhouse ML. A cause of chromate dermatitis among assemblers in an automobile factory. Brit J Ind Med 1963; 20:199-203.

42. Mathur AK, Srivastava AK, Singh A, Gupta BN. Sensitivity to chromium-containing automobile parts. Contact Dermatitis 1991; 24:65-66.

43. Marzulli FN, Maibach HI. Contact Allergy: predictive testing in humans. IN: Dermatotoxicology 4th ed p. 331.

44. Moller DR, Brooks SM, Bernstein DI, Delayed anaphylactoid reaction in a worker exposed to chromium. J Allergy Clin Immunol 1986; 877:451-456.

45. Hueper WC. Environmental carcinogenesis and cancers. Cancer Res 1961; 21:842-857.

46. Hueper WC, Payne WW. Experimental cancers in rats produced by chromium compounds and their significance to industry and public health. Am Ind Hyg J 1959; 20:274-280.

47. Levy LS, Venitt S. Carcinogenicity and mutagenicity of chromium compounds: the association between bronchial metaplasia and neoplasia. Carcinogenesis 1986; 7:831-835.

48. Steinhoff D, Gad ShC, Hatfield GK, Mohr U. Carcinogenicity study with sodium dichromate in rats. Exp Pathol 1986; 30:129-141.

49. Levy LS, Martin PA, Bidstrup PL. Investigation of the potential carcinogenicity of a range of chromium containing materials on rat lung. Br J Ind Med 1986; 43:243-256.

50. Glaser U, Hochrainer D, Kloppel H, Oldiges H. Carcinogenicity of sodium dichromate and chromium (VI/III) oxide aerosols inhaled by male Wistar rats. Toxicology 1986;42:219-232.

51. De Flora S, Bagnasco M, Serra D, Zanacchi P. Genotoxicity of chromium compounds. A review. Mutat Res 1990; 238:99-172.

52. Venier P, Montaldi A, Majone F, Bianchi V, Levis AG. Cytotoxic, mutagenic and clastogenic effects of industrial chromium compounds. Carcinogenesis 1982; 3:1331-1338.

53. Newbold RF, Amos J, Connell JR. The cytotoxic, mutagenic and clastogenic effects of chromium-containing compounds on mammalian cells in culture. Mutat Res 1979; 67:55-63.

54. Hamilton-Koch W, Snyder RD, LaVelle JM. Metal-induced DNA damage and repair in human diploid fibroblasts and Chinese hamster ovary cells. Chem-Biol Interact 1986; 59:17-28.

55. Newton MF, Lilly LJ. Tissue-specific clastogenic effects of chromium and selenium salts in vivo. Mutat Res 1986; 169:61-69.

56. Stella M, Montaldi A, Rossi R, Rossi G, Levis AG. Clastogenic effects of chromium on human lymphocytes in vitro and in vivo. Mutat Res 1982; 101:151-164.

57. Hansen K, Stern RM. Welding fumes and chromium compounds in cell transformation assays. J Appl Toxicol 1985; 5:306-314.

58. Elias Z, Poirot O, Schneider O, Daniere MC, Terzetti F, Guedenet JC, Cavelier C. Cellular uptake, cytotoxic and mutagenic effects of insoluble chromic oxide in V79 Chinese hamster cells. Mutat Res 1986; 169:159-170.

59. Sarto R, Cominato I, Bianchi V, Levis AG. Increased incidence of chromosomal aberrations and sister chromatid exchanges in workers exposed to chromic acid (CrO_3) in electroplating factories. Carcinogenesis 1982; 3:1011-1016.

60. Choi Y-J, Kim Y-W, Cha C-W. A study on sister chromatid exchanges in lymphocytes in some metal plating workers (Korean) Korea Univ Med J 1987; 24:249-257.

61. Biedermann A, Landolph JR. Role of valence state and solubility of chromium compounds on induction of cytotoxic mutagenesis and anchorage independence in diploid human fibroblasts. Cancer Res 1990; 50:7835-7842.

62. Aitio A, Jarvisalo J, Kiilunen M, Kalliomaki P, Kalliomaki K. Chromium. in Clarkson TW, Friberg L, Nordberg GF, Sager PR, eds. *Biological Monitoring of Toxic Metals*, New York, Plenum, pp 369-382.

63. Bianchi V, Celotti L, Lanfranchi G, Majone F, Marin G, Montaldi A, Sponza G, Tamino, G, Venier P, Zantedeschi A, Levis AG. Genetic effects of chromium compounds. Mutat Res 1983; 117:279-300.

64. De Flora S, Badolati GS, Serra D, Picciotto A, Magnolia MR, Savarino V. Circadian reduction of chromium in the gastric environment. Mutat Res 1987; 192:169-174.

65. Petrilli FL, De Flora S. Metabolic reduction of chromium as a threshold mechanism limiting its In Vivo activity. Sci Tot Environ 1988; 71:357-364.

66. Ivankovic S, Preussmann R. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. Food Cosmet Toxicol 1975; 13:347-351.

67. NIOSH testimony before OSHA Air Contaminants Standard 1988

68. Fed Register 54(12):2683-2685. (January 19, 1989)

69. 29 C.F.R. § 1910.10 (1990)

70. Mancuso TF. International Conference on Heavy Metals in the Environment. Toronto (Cited in EPA 1984[1])

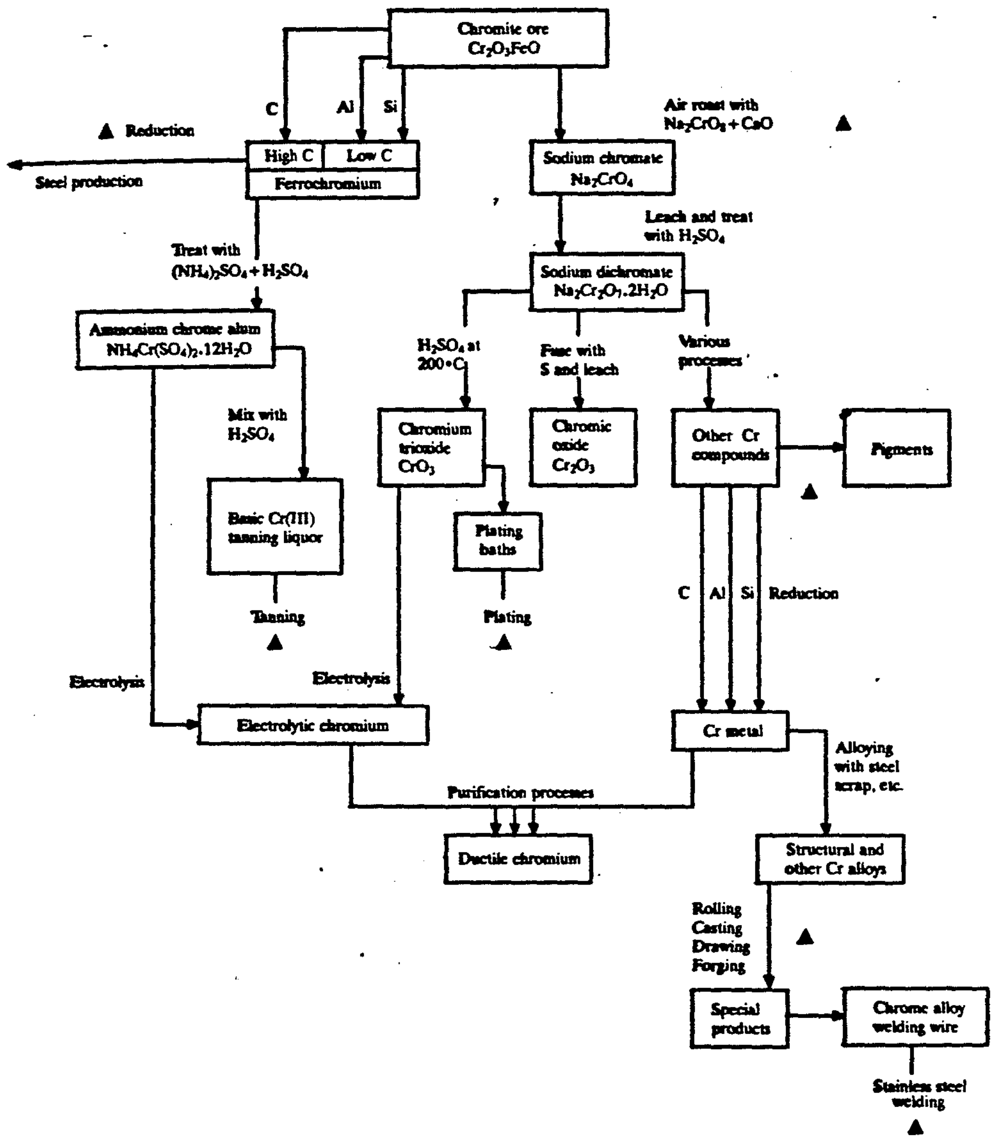
71. Langard S, Andersen A, Gylseth B. Incidence of cancer among ferrochromium and ferrosilicon workers. Br J Ind Med 1980; 37:114-120.

72. Axelsson G, Rylander R, Schmidt A. Mortality and incidence of tumours among ferrochromium workers. Br J Ind Med 1980; 37:121-127.

73. Pokrovskaya LV, Shabynina NK. On carcinogenic hazard in the production of chromium ferroalloys. Gig Tr Prof Zabol 1973; 10:23-26.

74. Industrial Union Department, AFL-CIO v. American Petroleum Institute. 448 U.S. 655 (1980).

Fig. 1. Simplified flow chart for the production of metallic chromium, chromium compounds and selected products from chromite ore. Processes for which occupational exposure levels to chromium are available are indicated by ▲[a]



[a]From Stern (1982)

Table 1 Occupations with potential exposure to chromium[a]

Abrasives manufacturers	Jewellers
Acetylene purifiers	Laboratory workers
Adhesives workers	Leather finishers
Aircraft sprayers	Linoleum workers
Alizarin manufacturers	Lithographers
Alloy manufacturers	Magnesium treaters
Aluminium anodizers	Match manufacturers
Anodizers	Metal cleaners
Battery manufacturers	Metal workers
Biologists	Milk preservers
Blueprint manufacturers	Oil drillers
Boiler scalers	Oil purifiers
Candle manufacturers	Painters
Cement workers	Palm-oil bleachers
Ceramic workers	Paper waterproofers
Chemical workers	Pencil manufacturers
Chromate workers	Perfume manufacturers
Chromium-alloy workers	Photoengravers
Chromium-alum workers	Photographers
Chromium platers	Platinum polishers
Copper etchers	Porcelain decorators
Copper-plate strippers	Pottery frosters
Corrosion-inhibitor workers	Pottery glazers
Crayon manufacturers	Printers
Diesel locomotive repairmen	Railroad engineers
Drug manufacturers	Refractory-brick manufacturers
Dye manufacturers	Rubber manufacturers
Dyers	Shingle manufacturers
Electroplaters	Silk-screen manufacturers
Enamel workers	Smokeless-powder manufacturers
Explosives manufacturers	Soap manufacturers
Fat purifiers	Sponge bleachers
Fireworks manufacturers	Steel workers
Flypaper manufacturers	Tanners
Furniture polishers	Textile workers
Fur processors	Wallpaper printers
Glass-fibre manufacturers	Wax workers
Glass frosters	Welders
Glass manufacturers	Wood-preservative workers
Glue manufacturers	Wood stainers
Histology technicians	

[a]From National Research Council (1974)