Chromium

Updated: December 2015

Symbol: Cr

Atomic number: 24

Atomic weight: 51.9961

Chromium is a hard, steel-gray metal that is highly resistant to oxidation, even at high temperatures. It is the sixth most abundant element in the earth's crust, where it is combined with iron and oxygen in the form of chromite ore.

Chromium is mined as chromite ($FeCr_2O_4$) ore. Roughly half the chromite ore in the world is produced in South Africa. Kazakhstan, India and Turkey are also substantial producers.

Chromium is obtained commercially by heating the ore in the presence of aluminum or silicon.

Chromium is a ubiquitous compound found in animals, plants, rocks, soil, and air.

Chromium is a very complex and versatile metal whose harmful effects are heavily dependent on valence. In addition to metallic chromium (valence 0), other valences found in industry are the +2, +3, +4, +5, +6 combining states [1].

Chromium forms a number of compounds in various oxidation states. Those of II (chromous), III (chromic) and VI (chromate) states are most important; the II state is basic, the III state is amphoteric (having characteristics of both an acid and a base and capable of reacting as either) and the VI state is acidic. Commercial applications mainly concern compounds in the VI state, with some interest in III state chromium compounds [2].

The two most stable forms are trivalent chromium (III) and hexavalent chromium (VI). In humans and animals, trivalent chromium is an essential element important for metabolism of glucose, fat, and protein [3].

Usage and exposure

Chromium is used in three basic industries:

metallurgical, chemical, and refractory (heat-resistant applications).

In the metallurgical industry, chromium is an important component of stainless steels and various metal alloys. Metal joint prostheses made of chromium alloys are widely used in clinical orthopedics.

In the chemical industry, chromium is used primarily in paint pigments (chromium compounds can be red, yellow, orange, and green), chrome plating. Chromium is also used in leather tanning and wood treatment. Smaller amounts are used in drilling muds, water treatment, catalysts, safety matches, copy machine toner, corrosion inhibitors, photographic chemicals, and magnetic tapes. Refractory uses of chromium include magnesite-chrome firebrick for metallurgical furnace linings and granular chromite for various other heat-resistant applications.

Routs of exposure

Dermal- trivalent salts are generally poorly absorbed through intact skin, however, absorption may occur.

Hexavalent salts are generally topically well absorbed, even through intact skin.

The chromium salts (chromates) used as an ingredient in the manufacture of many products such as cement, mortar, leather, paints and anti-corrosives are the cause of chrome sensitivity.

Work sources of chromates

- Allergic cement dermatitis is usually due to dichromates found in cement and is highest amongst workers handling wet cement;
- Primer paints containing zinc chromate and chromate dip to prevent corrosion of nuts and bolts is a cause of chromate sensitization in the automobile industry;
- Metal workers and welders of chromium steel alloys;
- Diesel locomotive radiator fluids, chromates used to prevent rust or radiators and pipelines;
- Plaster-like mixtures used in building repairs contain chromates
- Dye makers, color makers, paint makers, painters, basically any one who is exposed to pigments containing chromates;
- Engraving solutions;
- Pulp and paper industry;
- Artificial flower makers;
- Photographic workers;
- Pottery workers;
- Woodworkers;
- Explosives workers.

Home/personal sources of chromates

- Chrome-tanned leather goods including shoes, gloves and other wearable items and accessories;

- Cosmetics containing chromate-containing pigment (usually yellow-green colors);
- Disinfecting and bleaching agents where chromates are used for color and stabilizing properties;
- Safety matches, chromates commonly found in unlit and charred match heads;
- Green felt fabric used to cover snooker and card tables, chromates used in fabric dye;
- Paints, chromates used in anti-rust primer paints and also in the pigments for green-yellow paints;
- Tattoos containing chromate-containing pigment (usually yellow-green colors);
- Radiator coolants, chromates used to stop rusting;
- Internal exposure from dental or orthopedic implants that contain chromates;
- Chrome-plated materials, unlikely to be the cause of allergic dermatitis. Further investigation usually reveals nickel as the offending agent [4].

Oral - trivalent chromium salts are absorbed following ingestion. Hexavalent salts are converted by gastric juice to the trivalent form prior to ingestion.

Respiratory - metallic chromium, chromic salts (valences 0, +2, +3) are minimally absorbed following inhalation. Inhalation of highly water-soluble hexavalent chromium salts may result in systemic absorption [5].

The greatest occupational hazard historically has been in the processing of chromite ore to produce chromates, where workers were found to have a high incidence of lung cancer.

Exposure to chromium fumes occurs in the production and fabrication of stainless steel. Electroplaters are exposed to chromic acid mists.

Metabolism

Cr (III) is an essential dietary nutrient. It is required to potentiate insulin and for normal glucose metabolism. Chromium deficiency has been associated with impaired glucose tolerance, fasting hyperglycemia, glucosuria, elevated percent body fat, decreased lean body mass, maturity-onset diabetes, cardiovascular disease, decreased sperm count, and impaired fertility.

Trivalent (Cr [III]) and hexavalent (Cr [VI]) compounds are thought to be the most biologically significant. Cr (III) is an essential dietary mineral in low doses. Certain compounds of Cr (VI) appear to be carcinogenic, but insufficient evidence exists to determine whether Cr (III) or chromium metal can be human carcinogens. Cr (VI) is generally considered 1,000 times more toxic than Cr (III).

Chromium compounds may be absorbed through the gastrointestinal tract, the lungs, or the skin. The soluble hexavalent forms are much more readily absorbed than the insoluble trivalent forms. Intracellulary, hexavalent chromium is converted to the trivalent form, which binds to proteins and nucleic acids, resulting in chromium toxicity.

Particulate chromium (III) compounds can also enter cells by phagocytosis.

Cr (III) and Cr (VI) are naturally occurring stable oxidation states of chromium. Unlike Cr (III), Cr (VI) uses the anion transport system to enter the cell. Once transported through the cell membrane, Cr (VI) is rapidly reduced to Cr (V) and Cr (IV). These

intermediate states of chromium are reactive and can produce reactive oxygen species, which cause DNA strand breaks, base modification, lipid peroxidation, and transcription factor activation. In vitro experiments show hexavalent chromium compounds induce cell death through apoptosis [6].

Target organs: skin, upper and lower respiratory airways.

Health effects

Acute

Acute exposure to high concentration of chromic acid or chromates will cause immediate irritation of the eyes, nose, throat, and respiratory tract, resulting in burning, congestion, epistaxis and cough.

On contact with skin, hexavalent chromium compounds act as both irritants and sensitizers.

Inhaled concentrated chromic salts may result in pulmonary edema, which may be delayed up to 72 hours following exposure.

Following ingestion of chromates the gastric and intestinal mucosa are in danger of severe erosive injury.

Acute renal failure is common following large oral ingestions of hexavalent chromium compounds. Acute renal failure can occur following a dermal burn of 10% body surface area or less [Sullivan].

Chronic

Reactions to contact with chromates in an allergic individual include allergic contact dermatitis and irritant dermatitis. It may cause an airborne contact dermatitis. In addition chrome exposure may lead to ulceration of the skin and perforation of the nasal septum. Chrome ulcers and nasal septum perforation are most commonly seen

in industrial exposure cases and may occur without accompanying allergy to chromates.

Chrome ulcers or chrome holes are typically crusted, painless lesions revealing a 2-5mm pitted ulcer covered with exudates that most commonly occur on exposed parts of the body, mainly the hands, forearms and feet. They also develop readily at the site of insect bites, sores or other injuries. Initially nasal septum ulceration may be painless but with continued exposure the necrotizing effect of chromates to underlying tissues may become painful and lead to permanent scarring and disfigurement. This is still commonly found in workers exposed to strong chromate solutions in electroplating, tanning and chrome-producing manufacturers [New Zealand Dermatological Society].

Inhalation of trivalent chromium salts can cause occupational asthma.

Carcinogenicity

Of the occupational situations in which exposure to chromium occurs, highest exposures to chromium (VI) may occur during chromate production, welding, chrome pigment manufacture, chrome plating and spray painting; highest exposures to other forms of chromium occur during mining, ferrochromium and steel production, welding and cutting and grinding of chromium alloys.

Epidemiological studies carried out on workers in the chromate production industry have consistently shown excess risks for lung cancer. The workers in this industry may be exposed to a variety of forms of chromium, including chromium (VI) and (III) compounds.

Similarly, studies carried out on workers in the production of chromate pigments have also consistently shown excess risks for lung cancer. Workers in this industry are exposed to chromates, not only in the pigments themselves but also from soluble chromium (VI) compounds in the raw materials used in their production. Excess risk

for lung cancer has been clearly established in facilities where zinc chromate was produced, although other chromium pigments were also generally made in these plants.

Cases of nasal sinus cancer were reported in epidemiological studies of primary chromate production workers, of chromate pigment production workers and of chromium platers, indicating a pattern of excess risk for these rare tumors.

For cancers other than of the lung and sino-nasal cavity, no consistent pattern of cancer risk has been shown among workers exposed to chromium compounds.

No epidemiological study has addressed the risk of cancer from exposure to metallic chromium alone.

Chromium (VI) is *carcinogenic to humans (Group 1)*.

Metallic chromium and chromium (III) compounds are not classifiable as to their carcinogenicity to humans (Group 3) [7].

A Texas study investigated 12 toxicants that are released into the environment by industry (carbon tetrachloride, formaldehyde, methylene chloride, styrene, tetrachloroethylene, trichloroethylene, arsenic, cadmium, chromium, cobalt, copper, and nickel) with breast cancer incidence in Texas. Chromium was positively associated with the breast cancer rate [8].

New data have become available. IARC monograph, Volume 100C, determines that:

There is sufficient evidence in humans for the carcinogenicity of chromium (VI) compounds. Chromium (VI) compounds cause cancer of the lung.

Also positive associations have been observed between exposure to Chromium (VI) compounds and cancer of the nose and nasal sinuses.

Chromium (VI) is agent with limited evidence in humans for nasal sinus cancer.

Chromium (VI) compounds are carcinogenic to humans (Group 1) [9,10].

References

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